IMPACT OF EXTREME WEATHER EVENTS ON EMPLOYMENT AND INCOME IN THE BRAZILIAN SEMI-ARID REGION

FIDA
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SEMEAR INTERNACIONAL

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SALVADOR | MAY 2020

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VIVA O SEMIÁRIDO PROJECT (PVSA)

- Benefited Families: 22,000
- Families Headed by Young People: 6,600
- Families Headed by Women: 9,500
- IFAD Funding: US$ 20 million
- Government Funding: US$ 10.1 million

PAULO FREIRE PROJECT (PPF)

- Benefited Families: 60,000
- Families Headed by Young People: 16,052
- Families Headed by Women: 10,800
- IFAD Funding: US$ 40 million
- Government Funding: US$ 40 million

PROCASE PROJECT (SUSTAINABLE DEVELOPMENT OF CARIRI, SERIDÓ AND CURIMATAÚ)

- Benefited Families: 22,000
- Families Headed by Young People: 1,570
- Families Headed by Women: 10,800
- IFAD Funding: US$ 25 million
- Government Funding: US$ 15.5 million

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- IFAD Funding: US$ 45 million
- Government Funding: US$ 50 million

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- Benefited Families: 74,000
- Families Headed by Young People: 39,000
- Families Headed by Women: 37,000
- IFAD Funding: US$ 18 million
- Government Funding: US$ 42 million

IFAD's performance in Brazil with Semear Internacional program

The International Fund for Agricultural Development (IFAD) is a financial agency of the United Nations (UN) that, in partnership with state and federal governments, enters into loan and grant agreements to support rural development. In Brazil, IFAD's main investment focus is the semi-arid region, where it performs actions aimed at promoting productive projects to generate agricultural income, cooperatives, associations and access to markets. With promotion of nutritional food security and reduction of poverty in rural areas among its pillars, IFAD encourages the strengthening of activities whose priority audiences are women, young people and traditional communities.

IFAD has already provided an amount of approximately US$ 300 million for the implementation of 13 projects in Brazil. Six projects are in execution in 2020, with direct benefit to 250,000 families. Five of them are in partnership with state governments, through bilateral agreements: Paraíba (Procase Project – Sustainable Development of Cariri, Seridó and Curimataú), Bahia (Pró-Semiárido Project), Sergipe (Dom Távora Project), Piauí (Viva o Semiárido Project), and Ceará (Paulo Freire Project). In partnership with the federal government, the Dom Hélder Câmara Project (PDHC) covers 11 states: Pernambuco, Ceará, Rio Grande do Norte, Alagoas, Bahia, Piauí, Paraíba, Sergipe, Maranhão, Minas Gerais, and Espírito Santo.

In parallel with the projects, IFAD seeks to carry out actions that go beyond productive development in the communities served, encouraging access to information through donation programs, such as the Semear Internacional Programme (PSI), whose operationalization is supported by the Inter-American Institute for Cooperation on Agriculture (IICA). Operating in Brazil, PSI has the following axes: Knowledge Management; Monitoring & Evaluation; Communication; Policy Dialogues; and South-South and Triangular Cooperation. PSI works with the six projects supported by IFAD in Brazil, strengthening their capacities by carrying out activities that stimulate knowledge. The objective is to facilitate access to contextualized knowledge and innovations for coping with the semi-arid region.

Among the PSI's activities, there are exchange programs; training; workshops and seminars with technicians and project beneficiaries; technical training for public managers; institutional articulations; support for gender equality; support for the collection of socioeconomic data and methodization of results; book publications, and production of journalistic and communicational content in print and digital formats. In this way, the program has been making a significant contribution to the systematization and dissemination of good rural practices in IFAD's projects, both nationally and internationally.

Operation of each PSI's action component:

KNOWLEDGE MANAGEMENT

Training, exchange programs, thematic meetings and seminars are the main activities developed to strengthen knowledge and the knowledge exchange between projects, involving technician and beneficiaries. The most addressed themes are: access to markets, agroecology, gender, gastronomy, and goat farming. Many of these events result in publications that, in print and/or digital format, contribute to the enhancement and increased visibility of these good practices and successful experiences.

MONITORING & EVALUATION

Periodic training courses for technicians from these areas are carried out, with promotion of meetings in working groups and the involvement of professionals from other institutions. All IFAD's projects in Brazil use an integrated management system called Data.Fida, a great product developed by Semear Internacional for this component, which contributes to improving quality and accuracy of the information collected and processed by the projects.

COMMUNICATION

A component that permeates all others, Semear Internacional's Communication uses several channels, such as the portal and social networks, to make knowledge and information reach the most different audiences. Publications (books, booklets, manuals and studies), a collection of videos and photos and the database of good practices already listed can be found on the website, as well as texts created weekly and disseminated among IFAD's projects A recent product in this area is the Prêmio Semear Internacional de Jornalismo, award in its first edition that honors the best news reports in Brazil on good rural practices.

SOUTH-SOUTH AND TRIANGULAR COOPERATION AND POLICY DIALOGUES

The objective of South-South and Triangular Cooperation is to foster new knowledge and networks through the internationalization of its actions. Through exchange programs, training and seminars involving countries in Latin America and Africa, topics of common interest in family farming are addressed, identifying techniques and practices that can help rural workers in their daily lives. In addition, PSI seeks to facilitate the dialogue on public policies, with a view to supporting spaces aimed at the debate between civil society, governments, academia, and partners.

Learn more about PSI's actions; visit the virtual library and access the events held to join the network for the dissemination of good rural practices in the semi-arid region, accessing www.portalsemear.org.br.

Foreword

Water is a fundamental element for life, a fundamental asset not only for survival, but also for the individuals' well-being. Thus, its availability or scarcity is decisive for communities to develop economically and socially.

Considering the importance of water, the UN inserted the availability of drinking water, its sustainable use and access to sanitation in its 2030 Agenda for Sustainable Development (through Goal 6: Clean Water and Sanitation). This demonstrates the organization's commitment and understanding of the relevance of the topic and its (direct and indirect) impacts on health, education, work and income.

In Brazil, the Northeast is the region potentially most vulnerable to the effects of climate change, especially the semi-arid region, comprising 1,262 municipalities, distributed among the nine states in the region. The semi-arid region is characterized by a high rate of poverty and indicators of socioeconomic vulnerability.

Currently, the greatest threat to satisfactory water supply in the region is due to rapid climate changes driven by global warming phenomena. These changes are confirmed by the increase in the frequency of extreme events, which directly impact the availability and/or quality of water in a given region. This has been more present in the Northeast semi-arid region, historically affected by extreme weather events. Besides, there is the clear increase in water consumption over the past 20 years, and it is possible to realize the negative potentiation of an already catastrophic scenario.

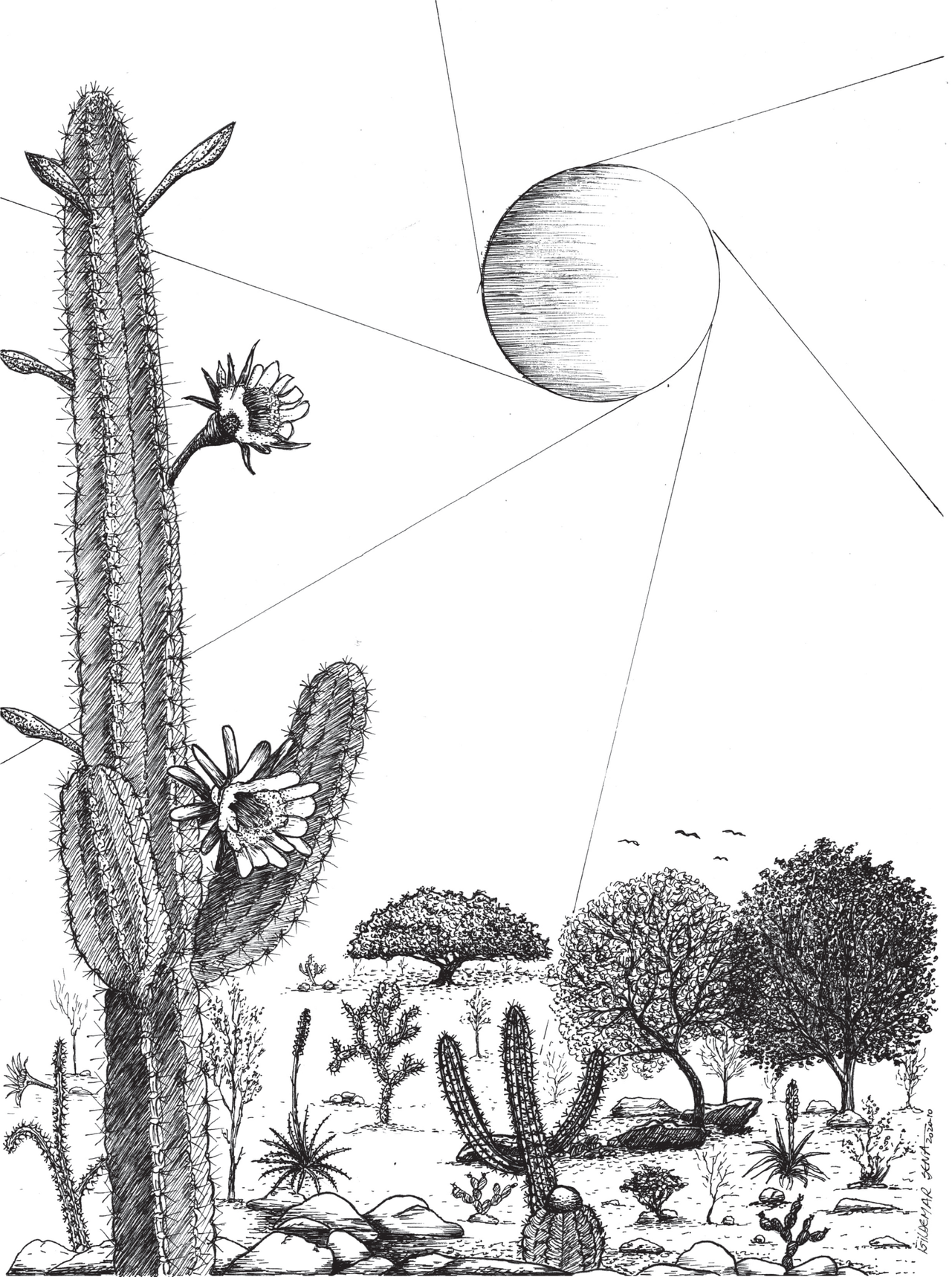
IFAD developed, based on the efforts of a multidisciplinary technical team formed by researchers (s) from the Federal University of Bahia (UFBA), a series of studies that can contribute to understanding this phenomenon and developing strategies to overcome it. This work was coordinated by the PSI's team, with IFAD's donation managed by IICA.

The result presented in this document aims to analyze the impact of extreme weather events on employment and income in the labor market in the municipalities of the Northeast and semi-arid region. For this purpose, three databases at municipal level were created for the Northeast region: climatic, formal labor market, and general labor market.

To this end, the team used descriptive analyzes and econometric measures to verify the main impacts identified. The results show that low rainfall and drought are associated with a sectoral reallocation of employment towards formal salaried work, while the portion of informal and self-employment is reduced. Employment reallocation, in response to the climate shock, generates an increase in average municipal incomes. The effects are more intense in the semi-arid region.

UFBA's and PSI's teams believe that sharing this information can contribute to seeking solutions and public policies improvement to confront poverty in Northeastern Brazil.

Good reading!



1.Introduction

Water is considered a fundamental resource for the individuals' well-being and is directly related to the results of health, education, labor and income of a country or region. The UN has included the availability and sustainable use of drinking water and sanitation in its 2030 Agenda for Sustainable Development as one of the seventeen Sustainable Development Goals. In addition, water use efficiency is essential to cope with scarcity and reduce its impacts (UNESCO, 2020). Droughts, which represent more than 5% of natural disasters and affect 1.1 billion people, may have their adverse effects intensified over the years as a result of climate change (CRED/UNISDR, 2015).

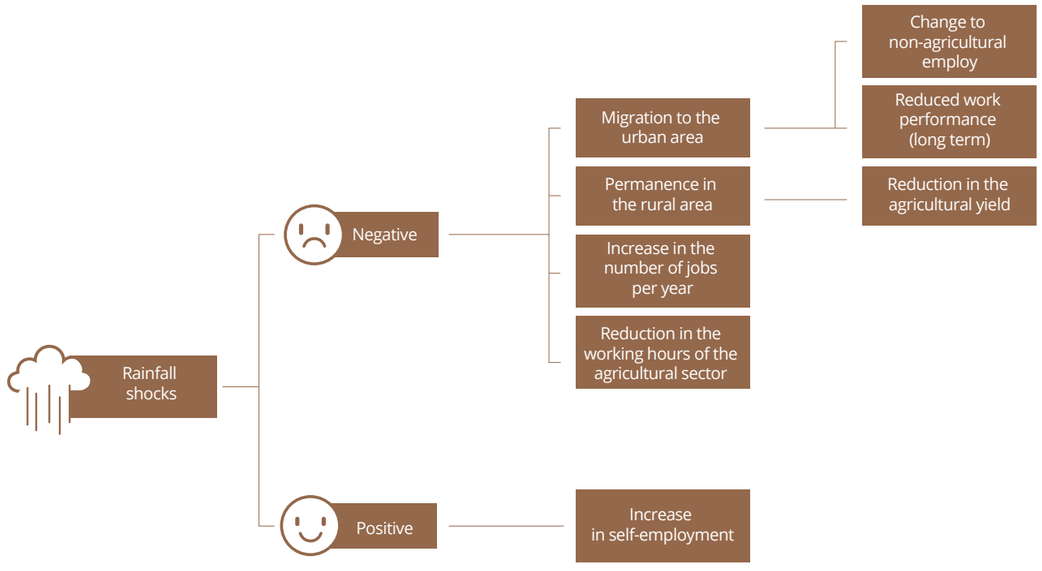
The Northeast region concentrates a large territorial extension of the Brazilian semi-arid region, which covers 1,262 municipalities, distributed among the nine states in the region, housing 12% of the Brazilian population and 37% of the region's population. The Northeast and the semi-arid Northeast, due to their natural characteristics, are most affected by climate change. In addition, the region has a high level of poverty and social vulnerability, which can increase the adverse effects of extreme weather events (ASA BRASIL, 2017).

According to data from the 2019 Continuous National Household Sample Survey (Pnad-Contínua), of the Brazilian Institute of Geography and Statistics (IBGE) (2020), Brazil had 72.4 million households, of which 97.6% had piped water, 88.2 % had access to the general water supply network and 85.5% had access to the general network as the main source of water supply. Among the

households where the general network was the main supply source, in 88.5% the service was available on a daily basis, while in the Northeast the daily supply coverage reached only 69% of households, the lowest among the regions. Water scarcity has direct effects on agricultural production and the income of families that depend on it. The reduction in agricultural production can, in turn, affect the generation of employment opportunities in the sector (Branco and Feres, 2018; Oliveira, Palialol and Pereda, 2019). Water scarcity and climate change can affect labor market outcomes with impacts on employment, income, labor productivity and migration.

In the empirical literature, it is possible to identify the impacts of climate change and weather extreme events on a wide range of labor market indicators, such as employment, income and migration. Climate change and weather extreme events can affect the labor market in several ways. The potential positive and negative direct effects of rainfall shocks on employment and income are described in Figure 1, elaborated from the evidence identified in the empirical literature. On the other hand, it is possible to identify indirect climatic effects on the labor market results, since water scarcity can affect workers' health and reduce labor productivity (THE LANCET, 2018).

FIGURE 1. **POTENTIAL IMPACTS OF RAINFALL SHOCKS ON THE LABOR MARKET**



Source: Own elaboration.

TABLE 1. CHARACTERISTICS OF THE LABOR MARKET IN THE NORTHEAST AND SEMI-ARID REGION: 2010

Variable (%)	North	Northeast	Semi-arid	Southeast	South	Midwest
Unemployment rate	8,73	9,75	8,10	7,54	4,68	6,64
Participation rate	54,16	52,26	51,03	59,29	63,09	62,04
Informal employment	39,93	42,80	55,10	22,81	21,11	28,85
Social security contributors	43,50	43,73	32,18	69,36	68,01	61,21
Self-employed workers	26,98	22,91	23,85	19,21	23,41	20,43
Agricultural sector jobs	23,03	24,17	35,86	7,39	15,15	11,65

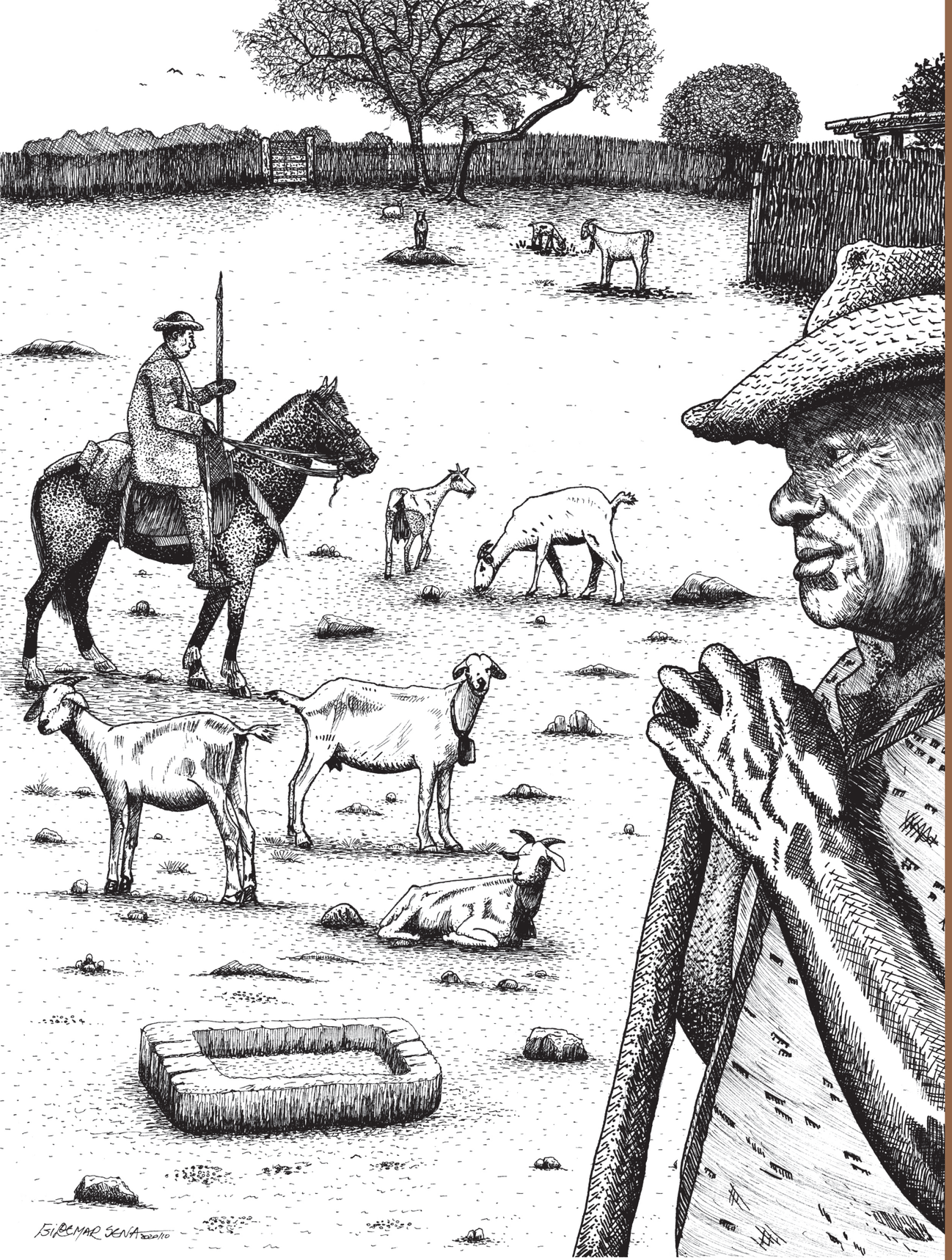
Source: Own elaboration based on Census (2010)

Table 1 shows the characteristics of the labor market in the Northeast and in the semi-arid Northeast, in 2010, in comparison with the other macro-regions in Brazil. The Northeast had the highest unemployment and informal employment rates and portion of agricultural sector jobs in relation to the other regions. In turn, the semi-arid region had higher informality and self-employment rates and portion of agricultural sector jobs in relation to the Northeast region. The Northeast had the lowest rate of participation in the labor market – ratio between the economically active population (PEA) and the working age population (PIA)[1] – among the regions, and the second lowest portion of jobs among workers who contributed to social security (alternative measure of formal employment). The rate of participation and workers who contributed to social security was even lower in the semi-arid region, characterized by a large portion of informal jobs and high unemployment and agricultural sector jobs rates.

In order to analyze the impact of extreme weather events – in particular drought occurrence – on young people's and adults' employment and income, a rainfall database was created for each municipality in the Northeast region, which allowed elaborating drought indicators. Total employment and income indicators were established based on public data from 2000 and 2010 Demographic Censuses (IBGE), while formal labor market data were extracted from the Annual List of Social Information (RAIS), for the period 2002-2017.

The report has five chapters, including this introduction. Chapter 2 presents the literature on climate impacts on the labor market, and Chapter 3 addresses the methods and data used for the analysis. Chapters 4 and 5 present and analyze the results.

[1] PEA corresponds to the Economically Active Population (Employed and Unemployed), while PIA represents the Working Age Population (10 years or older).



2. Literature review

Extensive literature analyzes the effects of climate change on health, income, agricultural or rural production, economic growth, and well-being indicators (Das Gupta, 2013; Tol, 2018). However, the number of studies that seek to assess how climate change and exposure to extreme weather events can affect the labor market results is still limited. In addition, large portion of the studies relating to climate change and the labor market addresses the effects on migration.

Studies that address the relationship between climate change, labor market and population dynamics investigate the effects of climate variations, or shocks associated with extreme weather events, on various labor market indicators. Some of these indicators are: migration and urban population; total labor income in the agricultural, rural-urban sectors, or family income; wage difference between genders; worker's health; hours worked; number of jobs; labor productivity; informality and self-employment; total employment, in the agricultural sector or outside this sector; labor force participation, and unemployment.

Mueller and Osgood (2009a) verify how the rainfall shocks in Brazil affect wages of families that have permanently migrated from rural to urban areas. With data from 1995 PNAD, the analysis focuses on rural families who have migrated to urban areas in the last nine years of the survey. The main result found shows that adverse climatic shocks in the short term reduce the migrants' wages in the long term. This would be because credit-restricted families might be willing to accept lower wages in urban areas after losing their productive assets during an adverse shock. In turn, Mueller and Osgood (2009b) investigated the effect of droughts on the Brazilian labor market from1992, 1993 and 1995 PNAD individual microdata. The results suggest long-term wage losses in rural areas, in addition to the immediate drought impact. The intensity of losses varied with dependence on agricultural income.

Barbieri et al. (2010) analyzed the effects of climate change on Brazil's interregional migration, focusing on the Northeast region, based on long-term projections (from 2025 to 2050). The results suggest that the predicted climate changes should have a more severe impact on the agricultural sector in the Northeast region, acting as an incentive factor for outbound migration from the region.

Zissimopoulos and Karoly (2010) examine the short and long-term effects of a natural disaster, Hurricane Katrina (which occurred in 2005 in the United States), on the labor market results related to working-age individuals in the most affected states (Alabama, Florida, Louisiana and Mississippi) and for specific groups defined by evacuation status. The study used data from the Current Population Survey (CPS), a monthly survey on 60,000 families, conducted by the Bureau of Labor Statistics. In the four states analyzed, there was a drop in labor force participation and employment rates and increases in the unemployment rate after the hurricane. But, with the exception of Mississippi, these results have returned to pre-Katrina levels, or even improved by the end of 2006. The rate of self-employment among employed workers increased in the post-Katrina period, mainly in Louisiana and Mississippi. However, groups of evacuees and those not evacuated from their homes as a result of the hurricane are heterogeneous. The group of individuals who left their residence, even if temporarily, was the most affected, with lower rates of labor force participation and higher rates of unemployment.

Rosenzweig and Udry (2014) analyze the effects of rain forecast and occurrence on migration and wages in the planting and harvesting stages. The authors constructed a general equilibrium model that deals with the sequential nature of production for the agricultural labor market in India. In the first period, prior to the rains, farmers choose agricultural inputs, while families, which do not own land, decide whether to stay in the village or migrate, both based on the rain forecast. In the second period of the model, there is the rainfall shock and the farmers maximize the profits, hiring the labor that remained in the village, due to the irrecoverable investments in the planting stage.

Results indicate that rainfall forecasts allow for early migration and improved well-being. The response of wages at the harvest stage, however, varies according to the forecast. A positive rainfall forecast (which reduces labor migration from the village), followed by adverse weather conditions, generates a sharper drop in wages in the harvest phase than would occur if there were no forecast. In other words, rainfall forecasts improve the allocation of labor on average, but aggravate wage volatility because they are imperfect.

Ayenew (2017) assesses whether rural families adapt the job offer to climate shocks, analyzing three main aspects: change to activities potentially less vulnerable to climate risks; adaptation by migration, and heterogeneous forms of adaptation between different family groups. To this end, the author used panel data for 2001 and 2004 in 2,936 small and medium-sized agricultural residences in 407 villages in the rural provinces of Mozambique. The results indicated a significant adaptation of the labor supply during and after episodes of positive and negative rainfall shocks. While negative shocks (drought) lead to greater involvement in salaried non-agricultural activities, positive shocks (rain) significantly increase self-employment in trade services and in small and micro enterprises. The adaptation of self-employment in trade services and in small and micro enterprises occurs locally, while salaried non-agricultural activities involve migration.

Results also indicate that there are heterogeneities in responses to the work adaptation based on land tenure, education of the head of the family, and endowment of labor.

Pecha Garzón (2017) investigates the probability of formally employed individuals migrating to informality due to exposure to extreme events (hurricanes and tropical storms). The data used are from the Labor Force Survey (LFS), from Jamaica, from 2004 to 2014. The empirical strategy explores the variation resulting from the time, intensity and geographic location of the storms in a model structure of endogenous choice in a panel of random effects. Results suggest that hurricanes do not interfere with unemployment, but positively affect the probability of transition to informality, regardless of whether the individual is initially formally or informally employed. When the storm marginal effects were studied, the probability of becoming an informal employee ranged between 8.5% and 14.5%, depending on the worker's initial state and when the storms occurred. The effect is mainly caused by the impact of hurricanes on the service sector.

Mahajan (2017) verifies the effect of rainfall shocks on the gender wage gap in Indian agriculture. Using a set of primary data from the Employment and Unemployment rounds (1993/1994, 1999/2000, 2004/2005, 2007/2008) of the National Sample Surveys (NSS), from India, and rain data from the data grid of the University of Delaware Center for Climatic Research, the authors constructed a panel of fixed effects of time and location (district).

The results indicate that, in general, shocks do not affect the wage gap, however, in the rice-producing regions fed by rain in India, women suffer a greater loss in their wages compared to men, thus increasing the wage gap between genders during the low rainfall years. The explanation presented is that greater demand for women in the crop cultivation severely affected by the variability of rainfall may make them more vulnerable to losses in the labor market during low rainfall years. That is, the effect of rainfall on the gender wage gap in agriculture depends on the gender roles underlying production technology in agriculture, which varies between farming systems.

Delazeri et al. (2018) examine whether climatic factors associated with economic, social and demographic factors influenced the urbanization rate – rural-urban migration – of municipalities in the Brazilian semi-arid region between 1991 and 2010. Through panel data with fixed effects, considering the spatial dependence, the authors

found evidence that climatic factors (mainly temperature) were decisive for the intensification of the urbanization process in the municipalities of the semi-arid region. The effect of the climate on the urbanization process was even more intense in the municipalities that largely depended on the agricultural sector. When simulating future scenarios, considering severe climate changes, the authors found that the urbanization process tends to accelerate over time.

Branco and Feres (2018) analyze whether rural families use allocation of labor allocation to mitigate the effect of drought shocks in the context of Brazilian Northeast. Using PNAD data between 2001 and 2014, restricting the sample to those living outside urban areas and to individuals aged 10 to 70 years, the authors constructed a fixed effects panel for municipality and year. The results indicate that a negative rainfall shock per year is associated with greater probability of having more than one job, less participation of agricultural activities in the total hours worked, and greater participation in secondary jobs. The effects are stronger in the poorest municipalities.

Oliveira and Pereda (2019) investigate the impact of climate change on internal migration and the spatial distribution of the workforce in Brazil, based on a spatial balance model, in which the climate influences workers' location choices through two channels: agricultural amenities and wages (given that agricultural productivity is a weather function). The main result indicates that, considering future climatic conditions, the Northeast would lose about 1.5% of its population to other regions, mainly to the Southeast. The Southeast and Center-West region, on the other hand, would gain 1.4% and 1.2% of its population, respectively, mainly due to increased migration. In other words, climate change resulting from the increase in temperature has the potential to deepen the regional inequality that exists in Brazil.

Oliveira, Palialol and Pereda (2019) verify whether there is a strong relationship between temperature and the productivity of non-agricultural work in formal labor markets in Brazil. For this end, they use data, at the worker level, on wages and monthly hours worked obtained from RAIS, and meteorological data from the National Institute of Meteorology (Inmet). Using the panel data methodology with fixed effects, the authors identify different heterogeneities of climatic effects on labor productivity. The results are in line with those presented by Mahajan (2017).

While women's wages are negatively affected by positive temperature shocks during the hot seasons, the results for men are not statistically significant. Data by sector and region also show heterogeneous climate effects on wages. Positive temperature shocks negatively affect many Brazilian regions, but the effect is limited by different average temperature thresholds. The results seem to be driven by sectors considered by the literature to be highly exposed to the climate, that is, those in which the work is usually done outdoors or the facilities are not acclimatized.

Mendoza and Valencia (2019) investigate whether workers in areas affected by a natural disaster are more likely to become informal in response to local shocks caused by the disaster, in the case of this study, an Mw 7.8 earthquake in Ecuador in 2006. Data were collected by the National Institute of Statistics and Censuses (Inec) in the National Quarterly Survey on Employment, Unemployment and Underemployment (Enemdu), for December 2015 (pre-earthquake) and December 2016 (post-earthquake). From the non-linear diff-in-diff method, using panel data at the individual level, the authors found evidence that the earthquake positively impacted the probability of being part of the informal sector if workers were located in affected areas. Significant differences between genders were also identified, indicating a causal effect for men, but not for women. When using the concept of informality based on jobs (informal employment) instead of on companies (informal sector), no robust evidence of causal effect was found.

Al-Bouwarthan et al. (2019) analyze how the intensity and duration of exposure to high temperatures impacts the health of workers who perform residential construction in Southeastern Saudi Arabia during the summer months. Based on surveys on workplace, in indoor and outdoor environments, at 10 construction sites in the province of Al-Ahsa, an assessment of exposure to thermal stress in workers was carried out according to the guidelines of the American Conference of Governmental Industrial Hygienists (ACGIH®) The main results indicated that construction workers were exposed to excessive thermal stress, both inside and outside the workplace, during much of the workday. Compliance with a ban on outdoor work at noon (12 pm-3 pm) was not effective in reducing the risk of heat stress. The greatest intensity of exposure was outside the workplace, between 9 am and 12 pm.

3.Methods

The econometric modeling of panel data will be used to estimate the impact of extreme weather events (drought) on labor and income indicators. However, before explaining the empirical model, the chapter presents a detailed description of the data and variables used.

3.1 DATA

For elaboration of result indicators of the labor market in the municipalities of the Northeast, IBGE, RAIS and the Ministry of Economy (ME) demographic census databases will be used. Censuses represent the main source of information on the population's living conditions in the country's municipalities and in different territorial areas (Brazil, large regions, federation units, mesoregions, micro-regions, metropolitan regions, municipalities, districts, sub-districts, and census sectors). The unit of information collection is the person residing, on the reference date, at home in the national territory. The census investigates important demographic and socioeconomic characteristics of families in country's each municipality, in addition to the domicile and migration characteristics. Results are published every 10 years, with the exception of a few decades, and the first officially registered census in Brazil was conducted in 1872 (IBGE, 2019).

Data on the general labor market in municipalities in the Northeast and in the semi-arid Northeast were extracted from Demo-

graphic Censuses (IBGE, 2000, 2010) and allow analyzing the broader municipal labor market, which includes both formal and informal jobs and other employment categories. This last characteristic is important, given that Brazil, like other developing countries, has a large portion of jobs in the informal sector, which makes it necessary to incorporate it in the labor market analysis However, informal data, at the municipal level, are only available in demographic censuses, which occur every 10 years and periodically present methodological changes that restrict the compatibility of all necessary variables.

The second database used to extract data from the labor market is RAIS (ME, 2019), a database of official administrative records on the formal labor market in Brazil. The data are of a census nature, since companies with formal employment relationships must declare information about their workers on an annual basis. It was instituted by Decree No. 76,900, of December 23, 1975, and aims to provide government institutions with information on the formal labor market that is used to control labor activity in the country, prepare labor statistics and meet needs of registration and control of systems associated with labor legislation (Guarantee Fund for Length of Service – FGTS; Collection and Concession and Social Security Benefits; Salary allowance for the Social Integration Program – PIS and for the Civil Servants Heritage Training Program – Pasep).

RAIS is an annual database that presents information at the municipal level on workers and companies in the country's formal labor market, such as schooling, gender, age, sector, occupation, and employment experience. RAIS main advantage is the annual provision of data on the labor market in Brazilian municipalities, allowing for more extensive longitudinal analyzes. The disadvantage is that the base is restricted to formal workers.

Tables 2 and 3 show descriptive statistics on the labor market of municipalities in the Northeast region, elaborated from the databases used in this report, comparing the semi-arid markets with those in other areas. Table 2 presents the descriptive statistics of the formal labor market (with a formal or statutory employment contract) for the Northeast region of Brazil, for the period 2002-2017, comparing the indicators of the municipalities inside and outside the semi-arid region.

The analysis of means over the period (2002-2017) shows that the values for hours worked, real income (at December 2017 prices) and number of establishments are higher for municipalities outside the semi-arid region. Mean values of the real gross domestic product (GDP) (in thousand reais, at 2017 prices) and the population density of the municipalities are almost four times higher outside the semi-arid region. Women are the majority in the formal labor market of the semi-arid region, while men are the majority outside it. About 72% of formal jobs in the semi-arid region are concentrated in the public administration sector, while the same sector concentrates about 59% of jobs outside the semi-arid region.

TABLE 2. DESCRIPTIVE STATISTICS OF THE FORMAL LABOR MARKET IN THE NORTHEAST: 2002-2017

Variable	Outside the semi-arid region	Semi-arid region
Experience (in months)	83,79	97,33
Age	37,36	37,97
Hours	39,14	37,99
Real income	1.302,2	1.203,96
Real GDP (thousand reais)	722.935,9	198.551,1
Density	156,18	43,37
Male (%)	51,87	43,28
Female (%)	48,13	56,72
No Education (%)	2,64	1,38
Incomplete Primary Education	22,32	22,18
Primary Education (%)	10,33	10,52
Incomplete High School	5,79	5,37
High School	42,14	41,52
Incomplete Higher Education	3,12	3,19
Higher Education (%)	13,65	15,83
Public Administration Sector (%)	58,75	72,08
Mining sector (%)	0,59	0,86
Manufacturing industry sector (%)	8,95	5,67
Public utility industrial services sector (SIUP) (%)	0,58	0,50
Construction sector (%)	1,88	1,52
Trade sector (%)	10,57	9,70
Services sector (%)	9,80	6,22
Agricultural/hunting/fishing sector (%)	8,87	3,46
Number of establishments	460,56	141,60
Small-sized establishment (up to 49 employees) (%)	92,88	92,60
Small-sized establishment (up to 99 employees) (%)	94,63	93,76
Medium-sized establishment (up to 499 employees) (%)	4,58	5,43
Large-sized establishment (500 +) (%)	0,80	0,81
Occupation: Leaders (%)	5,00	7,08
Occupation: Science/arts (%)	14,51	16,10
Occupation: Professional with technical high school degree (%)	14,08	13,93
Occupation: Administrative services (%)	16,31	17,44
Occupation: Services and trade (%)	24,94	27,77
Occupation: Agroforestry/fishing (%)	9,88	3,09
Occupation: Industry (%)	12,55	11,64
Occupation: Other (%)	2,46	2,70
Number of Municipalities	744	1.050

Source: Own elaboration based on RAIS (2002-2017)

TABLE 3. **DESCRIPTIVE STATISTICS OF THE LABOR MARKET IN THE NORTHEAST: 2000 AND 2010**

Variável	Fora do semiárido (Média)	Semiárido (Média)
Hours	38,26	36,66
Real income	540,33	491,63
Real urban income	616,22	584,48
Real rural income	394,12	354,67
Urban-rural income ratio	1,66	1,74
Real GDP (in thousand) per capita	5,69	4,16
Density	151,83	41,52
Formal establishments	387,77	109,17
Family heads (%)	48,87	47,38
Occupation: Leaders (%)	2,12	1,83
Occupation: Science/arts (%)	3,50	3,23
Occupation: Professional with technical high school degree (%)	5,21	4,82
Occupation: Services (%)	25,75	22,84
Occupation: Agroforestry/fishing (%)	43,01	48,52
Occupation: Industry (%)	15,46	14,72
Occupation: Other (%)	4,96	4,06
Self-employed (%)	27,01	23,61
Incomplete Primary Education	69,39	71,73
Incomplete High School	11,31	10,29
Incomplete Higher Education	15,16	13,61
Higher Education (%)	2,92	2,83
No specified Education (%)	1,22	1,54
Average of children	3,72	3,82
Formality (%)	30,07	23,06
Informality (%)	69,93	76,94
Male (%)	65,98	64,96
Female (%)	34,02	35,04
10-14 years old (%)	2,97	3,72
15-29 years old (%)	36,90	35,26
30-59 years old (%)	53,50	52,93
60 + (%)	6,65	8,11
White (%)	23,91	32,85
Black (%)	10,67	7,00
Brown (%)	63,75	58,86
Other races (%)	1,66	1,30
Agricultural sector (%)	41,52	48,67
Industry sector (%)	6,72	6,27
Trade sector (%)	10,86	9,75
Services sector (%)	23,67	21,01
Public Sector (%)	6,06	6,16
Other sectors (%)	11,18	8,14
Urban employment (%)	56,00	48,84
Rural employment (%)	44,00	51,16
Unemployment rate (%)	11,22	9,12
Urban unemployment rate (%)	13,73	11,83
Rural unemployment rate (%)	7,45	6,20
Urban population (%)	56,70	49,63
Rural population (%)	43,30	50,37
Agriculture GVA gross value added (%)	22,45	16,11
Industry GVA gross value added (%)	14,49	12,06
Services GVA (public administration included) (%)	63,07	71,83
Number of Municipalities	744	1.050

* GVA: Gross Value Added

Source: Own elaboration based on Demographic Census (2010)

Table 3 presents the descriptive statistics for the formal and informal labor market in the Northeast region based on data from 2000 and 2010 Demographic Censuses. The analysis of the indicator mean values of the general labor market, for 2000 and 2010, shows that the municipalities in the semi-arid region have lower real income (at prices of July 2010), real GDP per capita, population density and number of formal establishments and less average hours worked, and higher rates of informality and employment in the rural area and agricultural sector. The analysis of the urban-rural income ratio allows us to conclude that the urban and rural income inequality is greater in the semi-arid Northeast. Preliminary statistics suggest that the semi-arid Northeast has low relative economic performance and its formal labor market is heavily dependent on public jobs, while informality prevails, on average, in most of the existing jobs.

For the analysis of rainfall and temperature, a historical series of precipitation and temperature was elaborated using data from the Terrestrial Air Temperature and Terrestrial Precipitation Gridded Monthly Time Series (Matsuura and Willmott, 2009). This database has monthly information on these two variables over a distance of 0.5º × 0.5º (0.5º corresponds to approximately 56 kilometers). The procedures were the same as those adopted by Rocha and Soares (2015). From these monthly data per municipality, the following variables were collected (or created):

- Monthly rainfall volume in the municipality;
- Mean monthly historical rainfall volume (1950-2017) in the municipality;
- Standard deviation of the mean monthly historical rainfall volume.

From these variables, an indicator for the drought occurrence in each month t of municipality j was created. The elaboration of this variable follows the same approach adopted by Rocha and Soares (2015), according to Equation (1):

$$Drought_{jt} = \begin{cases} 1 \text{ if } Drought_{jt} < (Mean\ hist.\ rain_j - SD\ hist.\ rain_j) \\ 0, \text{ otherwise} \end{cases} \quad (1)$$

Where:

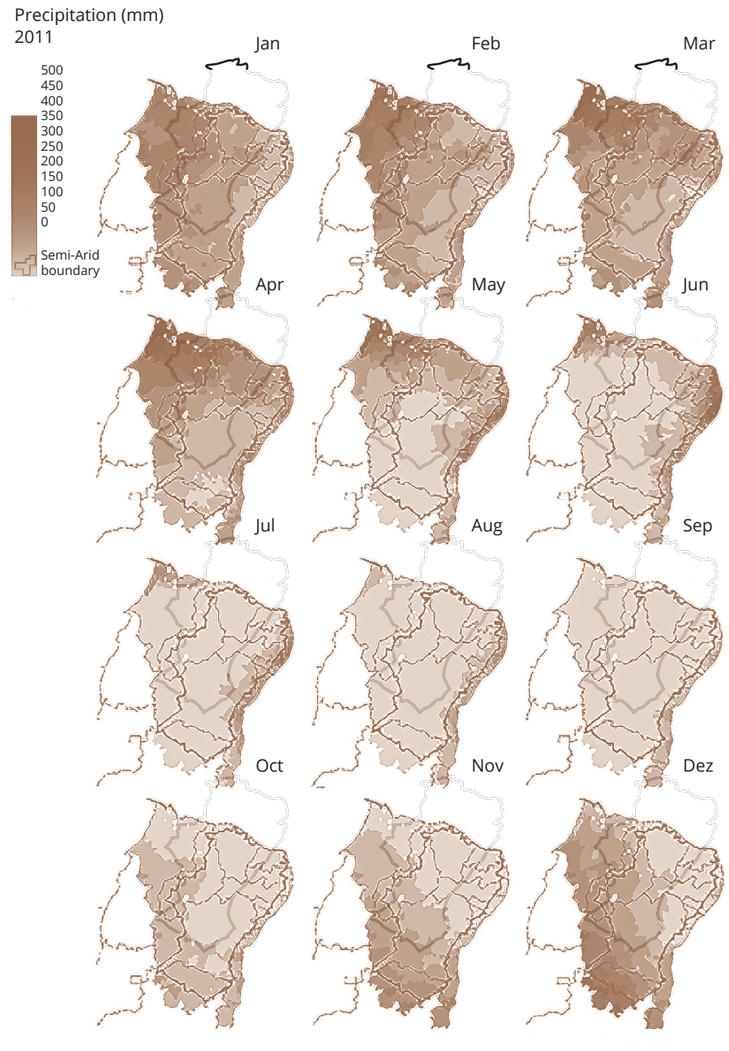
- j is a subscription for each municipality;
- t is the month (or set of months) in which the rainfall indicator was computed.

The mean monthly historical rainfall is the average rainfall for each month (or months) in the municipality, between 1950 and 2017, and the SD is the historical standard deviation for the same period.

3.2 INITIAL EVIDENCE

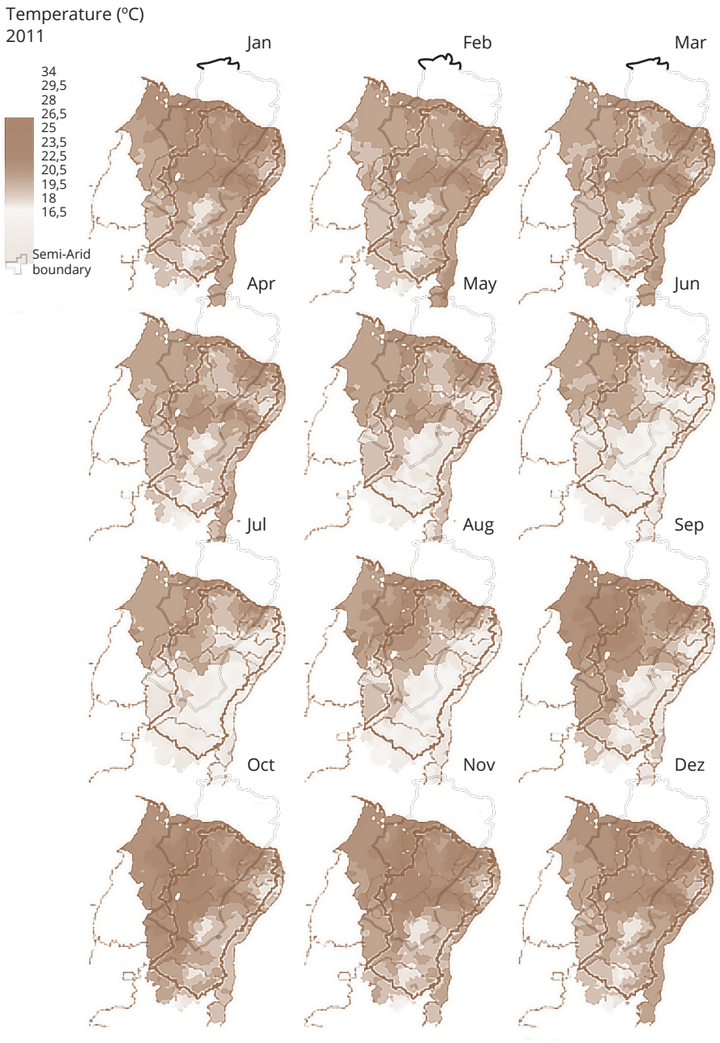
Figures 2 and 3 show monthly data on rainfall and temperature, on the Northeast region' maps, referring to 2000. These figures show that in the second half of the year there is a more pronounced period of low rainfall, while temperatures are higher.

FIGURE 2. RAINFALL INDEX OF THE NORTHEAST REGION PER MONTH: 2000



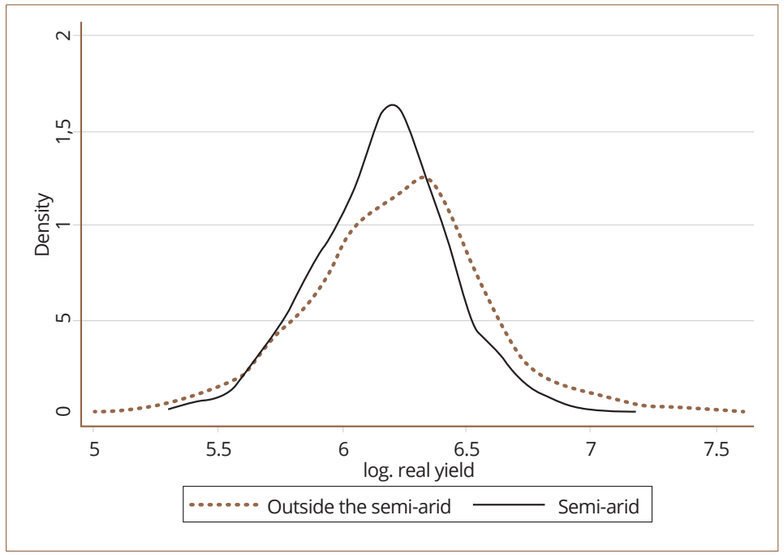
Source: Da Mata et al. (2019).

FIGURE 3. TEMPERATURE INDEX OF THE NORTHEAST REGION PER MONTH: 2000



Source: Da Mata et al. (2019).

FIGURE 4. INCOME DISTRIBUTION IN THE NORTHEAST LABOR MARKET: 2000 AND 2010



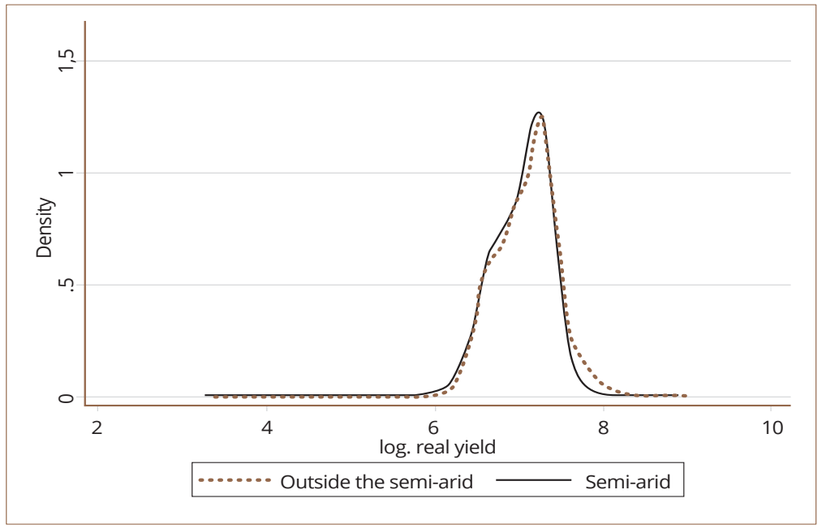
Source: Own elaboration based on Demographic Census (2010).

The following analyzes were based on data from formal workers (RAIS, 2002-2017) and from all workers, available in the Demographic Census (IBGE, 2000, 2010).[2] Figures 4 and 5 show the distribution of income in the labor market in the Northeast. Figure 4 shows the distribution of income in the total labor market, for 2000 and 2010. The distribution of data indicates that workers in municipalities outside the semi-arid region have higher incomes than those in municipalities in the semi-arid region. In turn, income in the semi-arid region is more symmetrical in relation to its average, which is lower than the average income of workers who are outside the semi-arid region.

[2] Chart 1 of the empirical strategy section, presents the complete description of the variables and their data sources.

Figure 5 shows the distribution of income in the formal labor market in the Northeast, from 2000 to 2017. It is possible to notice that distribution of income both in the municipalities of the semi-arid region and in those which are outside it are more to the right, that is, the wages for formal workers are higher, on average. In addition, wage inequality is lower in the formal segment, between the two groups (semi-arid region and outside the region), given the overlapping of distributions.

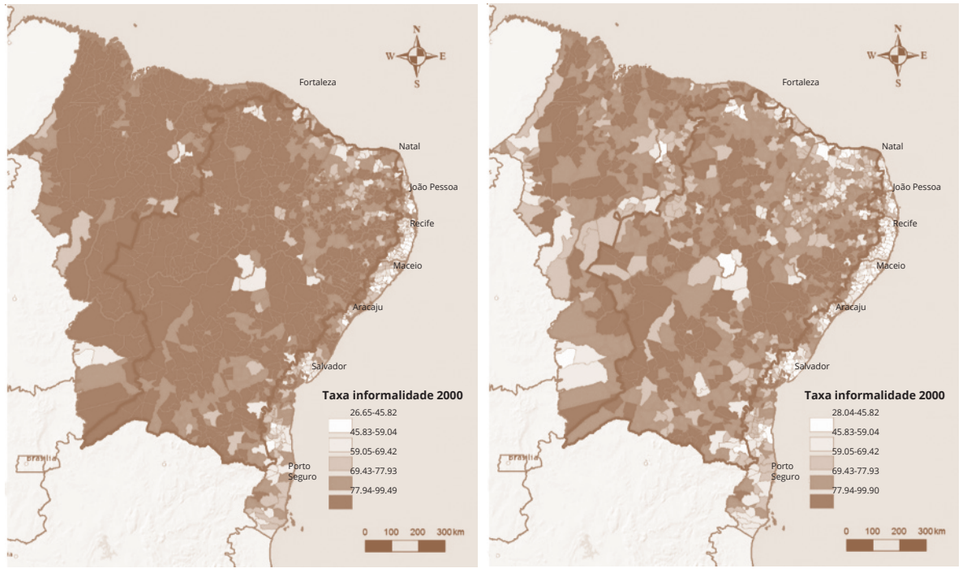
FIGURE 5. INCOME DISTRIBUTION IN THE NORTHEAST FORMAL LABOR MARKET: 2002 TO 2017



Source: Own elaboration based RAIS (2002-2017).

Figures 6 and 7 show, respectively, the informality rate in 2000 and 2010 and the number of formal jobs in 2002 and 2010, for the Northeast and the semi-arid region. In Figure 6, it is possible to observe a drop in the informality rate between these two periods: in 2000, almost the entire map is covered by darker green, while in 2010 many municipalities are covered by lighter green shades, demonstrating this drop in informality, including in semi-arid municipalities. In turn, Figure 7 shows an increase in the number of formal jobs in the Northeast region as a whole, although there is an area in the semi-arid region where this trend seems less evident.

FIGURE 6. INFORMALITY RATE IN THE NORTHEAST AND SEMI-ARID REGION: 2000 AND 2010



Source: Own elaboration based on Demographic Census (2000, 2010).

FIGURE 7. FORMAL EMPLOYMENT IN THE NORTHEAST AND SEMI-ARID REGION: 2002 AND 2010

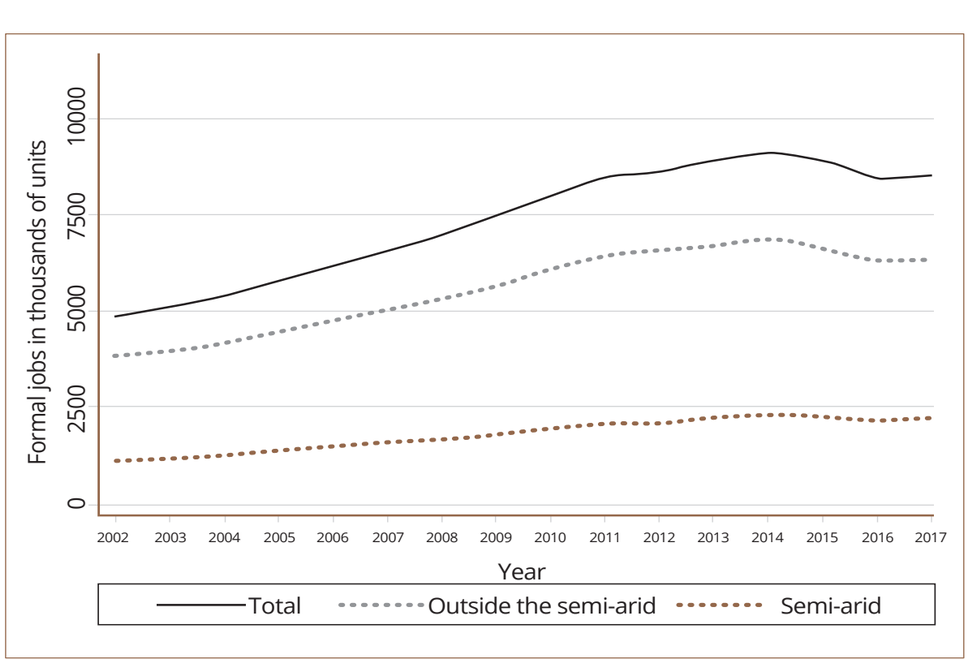
Source: Own elaboration based on Demographic Census (2000, 2010).

It is important to remember that the decade under analysis was a period of intense changes that contributed directly and indirectly to this change. Although much of the creation of formal employment can be attributed to the cycle of economic growth that the country experienced during this period, the government policies implemented represent a significant part of these results.

Several actions contributed to the expansion of the domestic market, such as income transfer policies, such as *Bolsa Família*, and the minimum wage appreciation policy, directly impacting the families' purchasing power and, therefore, the labor market. It is also possible to mention the expansion of credit to companies and consumers, as well as direct incentives for the formalization of workers, such as the creation of the individual micro-entrepreneur (MEI) and the Constitutional Amendment 72/2013, which establishes equal labor rights to domestic workers in relation to other urban and rural workers.

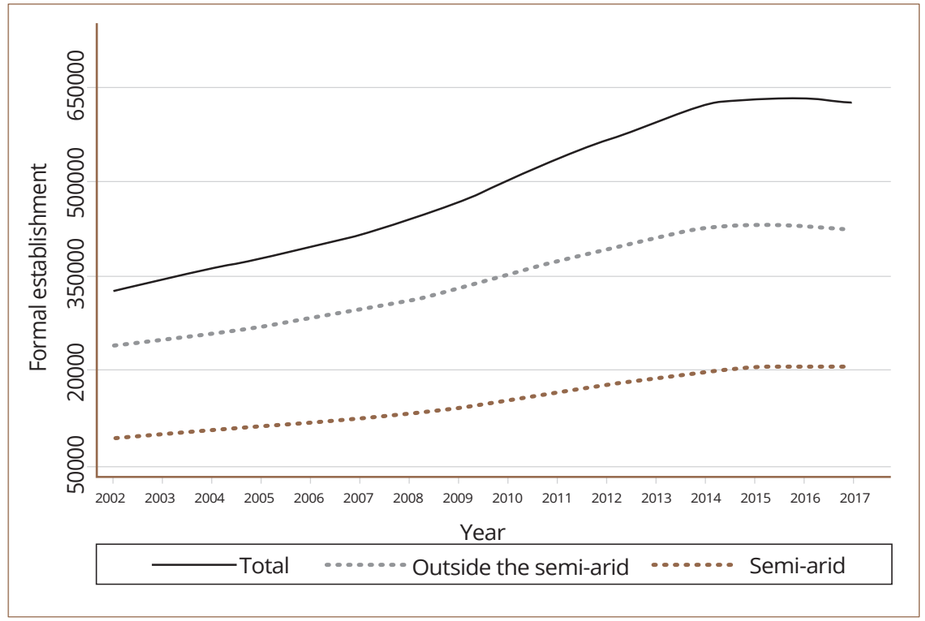
Figures 8 and 9 show, respectively, the evolution of jobs and formal establishments in the Northeast, inside and outside the semi-arid region, between 2002 and 2017.

FIGURE 8. EVOLUTION OF FORMAL EMPLOYMENT IN THE NORTHEAST AND SEMI-ARID REGION: 2002-2017



Source: Own elaboration based on RAIS (2002-2017).

FIGURE 9. EVOLUTION OF FORMAL ESTABLISHMENTS IN THE NORTHEAST AND SEMI-ARID REGION: 2002-2017



Fonte: elaboração própria a partir da Rais (2002-2017).

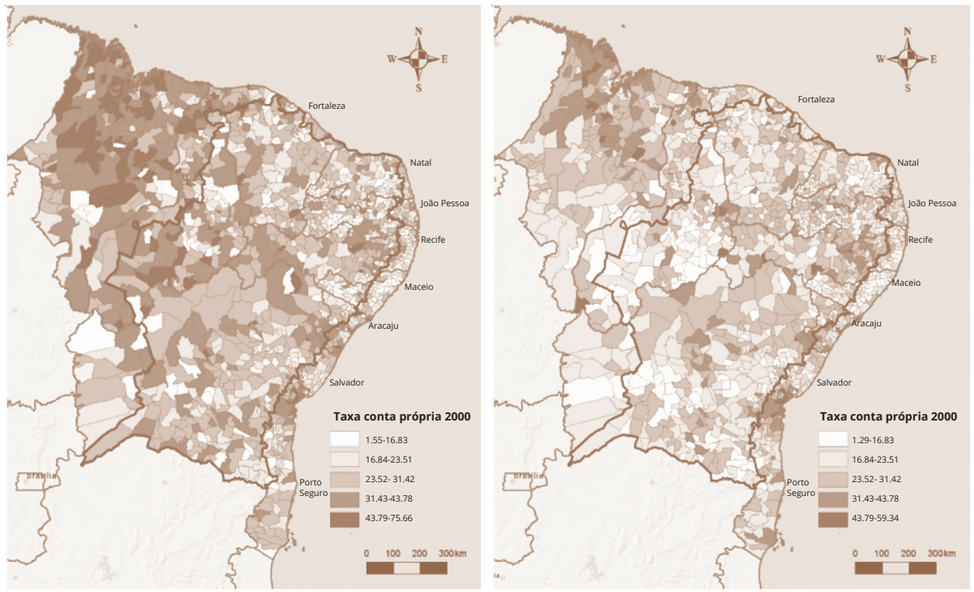
In general, the total growth of jobs and formal establishments in the Northeast seems to have been driven mainly by the growth of these variables in the municipalities that are outside the semi-arid region. Although the figures show very similar evolutions, it is possible to notice a slightly more pronounced drop in total employment in relation to the total of establishments from 2014, once again influenced mainly by formal jobs outside the semi-arid region. What is most noticeable about these two figures, however, is the large number of jobs (in thousand units) and formal establishments in municipalities outside the semi-arid region in relation to those in the semi-arid region, evidencing the great inequality in the distribution of jobs and establishments in this region.

Figure 10 shows the changes that occurred between 2000 and 2010 in the self-employed workers rate in the Northeast and in the semi-arid region. Based on the legend, the municipalities with the highest rates are represented in darker green shades. In the 2010 graph, most municipalities have a much lighter shade, compared to the 2000 graph, and it is possible to see a drop in the portion of self-employed workers over the analyzed period. It is interesting to note that, in 2000, the highest rate of self-employment was 75.68,

while in 2010 the highest rate was 59.34. This evidence indicates a reduction in self-employment even among the municipalities that had the highest rates in 2000. Likewise, there was a reduction in the lowest rate observed between the periods.

What is presented in these figures is in line with what was discussed earlier, regarding the drop in the informality rate and the increase in the number of formal workers in the Northeast and the semi-arid region.

FIGURE 10. SELF-EMPLOYED WORKERS RATE IN THE NORTHEAST AND SEMI-ARID REGION: 2000 AND 2010



Source: Own elaboration based on Demographic Census (2000, 2010).

3.3 EMPIRICAL STRATEGY

This project will assess the effects of climate change and extreme weather events on young people's and adults' results in the labor market in municipalities in the Northeast region, in particular on those located in the semi-arid region. For this purpose, the following result indicators will be used:

- Labor income;
- Hours worked;
- Number of formal jobs;
- Number of small-sized establishments (up to 49 employees)[3];
- Number of self-employed workers;
- Number of informal jobs;
- Number of individuals in the urban area.

Chart 1 shows the labor and income indicators of the labor market, selected to assess the effect of climate change and exposure to extreme events in municipalities in the Brazilian Northeast region, their temporal availability and the sources of the respective data.

The report proposes, as a methodology for analyzing the effects of climate change and extreme events on labor and income indicators, the construction of a panel database for municipalities in the Brazilian Northeast region, according to the time availability of Census (2000, 2010) data, with the most recent data from RAIS (2002-2017) and with the econometric estimation of panel data models. The panel (or longitudinal data) is a set of data in which the same research units have to be monitored over time. The advantage of this data structure is that it allows temporal analyzes, which offer a greater number of observations and variability of the information analyzed. In addition, longitudinal data allows dealing with specific local (or individual) factors that can explain the results of interest, such as geographic, geological and natural aspects, as well as cultural and historical factors.

[3] The criterion of establishment's size by the number of employees of the Brazilian Micro and Small Business Support Service (Sebrae, 2018) was adopted, according to which trade and services establishments are classified as small-sized if they present up to 49 employees.

CHART 1. **LABOR MARKET INDICATORS**

Indicator	Description	Source/period
Labor income	Average real labor income in the municipality	2000 and 2010 Census
2002-2017 RAIS	Média de horas trabalhadas no município	Censo 2000 e 2010 Rais 2002-2017
Hours worked	Mean of hours worked in the municipality	2000 and 2010 Census
2002-2017 RAIS	Número de estabelecimentos formais que possuem até 49 trabalhadores registrados	Rais 2002-2017
Number of formal jobs	Number of formal workers in the municipality	2002-2017 RAIS
Number of small-sized establishments (up to 49 employees)	Number of small-sized establishments that have up to 49 employees working on the books	2002-2017 RAIS
Number of self-employed workers	Number of self-employed workers among the employed people in the municipality	2000 and 2010 Census
Number of informal workers	Number of people working informally. The following are classified as informal workers: 1. employees working off the books and who do not contribute to social security; 2. self-employed employer and workers who do not contribute to social security	2000 and 2010 Census
Number of workers in the urban area	Number of employed people residing in the urban area of the municipality	2000 and 2010 Census

Source: Own elaboration.

The specifications for the econometric estimation of the models, based on the indicators of the municipal labor markets, are defined by Equation (2).

$$y_{it}=\beta_0+\beta_1 X_{it}+\gamma Clima_{it}+\delta_t T_t+\alpha_i+\varepsilon_{it} \quad (2)$$

Where:

- y_{it} are the labor market indicators of municipality *i* in year *t* (Chart 1);
- X_{it} are the socioeconomic characteristics of municipality *i* and year *t* (Chart A.1);
- $Clima_{it}$ are the variables of climatic variations and occurrence of extreme events in municipality *i* and year *t*;
- T_t are indicators of temporal shocks (annual *dummy* variables);
- α_i are the specific local effects, fixed in time, and not observed (municipal fixed effects);
- ε_{it} is the model error term for municipality *i* in year *t*.

The labor market indicators to be analyzed were presented in Chart 1. The local socioeconomic characteristics, which explain the selected indicators and have to be used as control variables in the models, will be based on studies of theoretical and empirical literature, which relate the labor market to the effects derived from climate change, as well as the availability of information on databases at the municipal level.

In this sense, the following municipal characteristics must be included: GDP; portion of workers per level of education; population density; sectoral employment; occupational employment; number and size of formal establishments, among other variables specific to each model. The variables defined in nominal values (in reais) will be corrected by the price variation between the years, using IBGE's Broad National Consumer Price Index (IPCA). Chart A.1, in Appendix A, presents the set of control variables that have to be included in the econometric model, for each result indicator, and their sources. Chart A.2 presents the categories that will be used as a reference for qualitative variables in the model estimates, based on their original categorical classifications.

The climate change indicators ($Climate_{it}$) that will be adopted in this report were based on empirical studies in the literature and are defined as follows:

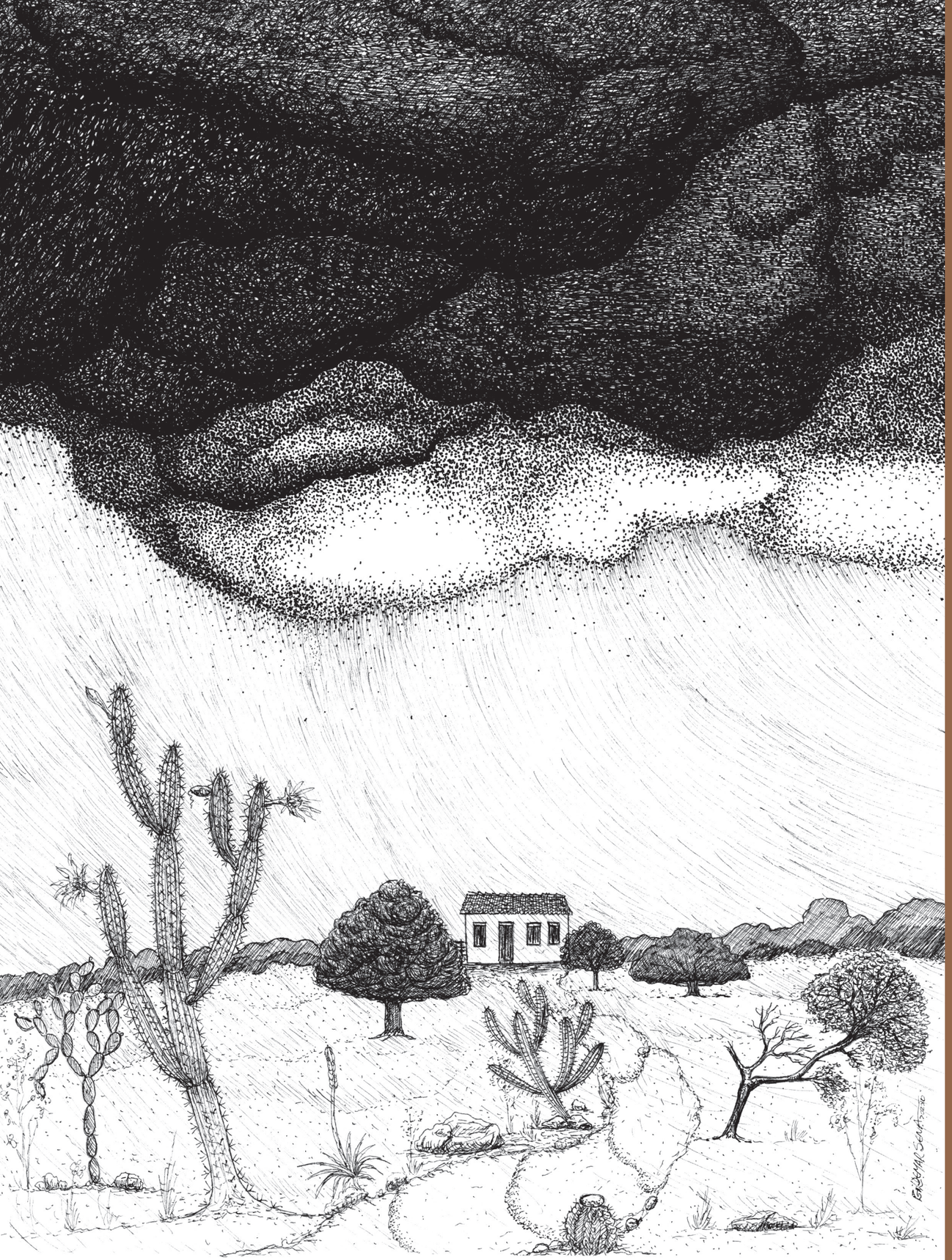
- Rainfall volume in the month prior to the month of research data collection;[4]
- Deviation in rainfall of the month prior to the month of the research data collection, in relation to the rainfall historical mean in the same month (since the 1950s); and
- Indicator variable for the occurrence of drought situations (rainfall volume in the month prior to the month of research collection must be lower than the historical mean deviation of the respective month).

Based on these indicators, it is possible to assess whether the municipalities' labor markets are adversely affected due to the effects of climate change and extreme weather events.

For econometric estimation, specific methods for panel data models will be used. It is assumed that, for the models of interest in this report, the fixed effect (FE) method is more appropriate, since it allows controlling specific and unobserved municipal characteristics, as long as they are constant throughout the analysis period and influence the behavior of the other variables included in the models, as well as the result variables (Wooldridge, 2002).

Finally, it is worth mentioning that, in order to investigate whether there are differences in the behavior of the indicators analyzed between the municipalities that comprise the semi-arid region and the others in the Northeast region, the models will also be estimated, including only the municipalities in the semi-arid region. This analysis allows verifying whether the climatic variables affect the municipalities of the semi-arid Northeast differently.

[4] July 31 was the initial reference date for the demographic censuses in 2000 and 2010, for the investigation of households and their residents (IBGE, 2019). The reference date for the information registered in RAIS is December 31 of each year (ME, 2019).



4.Results

This chapter presents the results of estimates of the econometric model adopted to analyze the impact of climatic shocks on labor market indicators. Table 4 shows the estimated results to verify the effect of climate impacts on formal labor market indicators. Three measures of climatic effects are used: (1) rainfall volume in the month prior to the month of research data collection; (2) rainfall deviation of the month prior to the month of the research data collection, in relation to the rainfall historical mean in the same month (since the 1950s); and (3) variable that indicates drought occurrence (rainfall volume in the month prior to the month of research data collection must be lower than the historical mean deviation of the respective month). Panel A presents the results when all municipalities in the Northeast are considered; in panel B there are only the municipalities located outside the semi-arid Northeast, and in panel C only the municipalities belonging to the semi-arid Northeast.

TABLE 4. **IMPACTS OF CLIMATIC VARIABLES OF THE PREVIOUS MONTH ON EMPLOYMENT AND INCOME IN THE FORMAL LABOR MARKET IN THE NORTHEAST REGION: 2002-2017**

Panel A: All the municipalities				
Period: 1 month	Income	Employment	Hours	Small-sized establishments
Rainfall volume	-0.0000	0.0004***	-0.0008	0.0003***
	(0.0000)	(0.0001)	(0.0007)	(0.0000)
Notes	26865	28643	26865	26730
Monthly historical deviation	-0.0010	0.0109***	-0.0812**	0.0030
	(0.0017)	(0.0030)	(0.0332)	(0.0020)
Notes	26045	27791	26045	25910
Drought	0.0040	0.0152*	0.1038	0.0255***
	(0.0041)	(0.0081)	(0.0827)	(0.0057)
Notes	26,880	28,659	26,880	26,745
Panel B: Outside the semi-arid region				
Period: 1 month	Income	Employment	Hours	Small-sized establishments
Rainfall volume	0.0001**	0.0004***	0.0007	0.0004***
	(0.0000)	(0.0001)	(0.0008)	(0.0001)
Notes	11125	11858	11125	11059
Monthly historical deviation	0.0041	0.0160***	0.0017	0.0076**
	(0.0028)	(0.0056)	(0.0448)	(0.0033)
Notes	10795	11516	10795	10729
Drought	-0.0065	0.0157	-0.0032	0.0077
	(0.0065)	(0.0136)	(0.1161)	(0.0094)
Notes	11,140	11,874	11,140	11,074
Panel C: semi-arid region				
Period: 1 month	Income	Employment	Hours	Small-sized establishments
Rainfall volume	-0.0001**	0.0003**	-0.0026**	0.0001**
	(0.0001)	(0.0001)	(0.0012)	(0.0001)
Notes	15740	16785	15740	15671
Monthly historical deviation	-0.0045**	0.0042	-0.1309***	-0.0023
	(0.0021)	(0.0033)	(0.0481)	(0.0025)
Notes	15250	16275	15250	15181
Drought	0.0135***	0.0204**	0.1705	0.0409***
	(0.0050)	(0.0102)	(0.1167)	(0.0069)
Notes	15,740	16,785	15,740	15,671
Socioeconomic	Yes	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes

Notes: the month precedes data collection; standard errors in parentheses; clustered errors at the municipal level; significance level: *p < 0.10, **p < 0.05, *** p < 0.01.

Source: Own elaboration.

The results suggest that the rainfall volume is positively related to the number of formal jobs and small-sized establishments, a result observed in all samples analyzed, although the effects are very limited (around 0.04% and 0.03%) and their magnitude is lower in the semi-arid region (0.03% and 0.01%). For the sample of municipalities outside the semi-arid region, the rainfall volume has a positive impact on formal income (0.01%), while the increase in rainfall negatively impacts income (-0.01%) and the number of hours worked (reduction of 0.0026 in average hours) in the formal segment for municipalities in the semi-arid region.

The monthly rainfall deviation also affected positively formal employment (1% in the total sample and 1.6% outside the semi-arid region), except in the semi-arid region, which lost significance. Likewise, the deviation was negatively related to income (-0.4%) and hours worked (reduction of 0.13 in average hours) in the semi-arid region, a result compatible with the rainfall volume, although the magnitude is greater. In relation to the impact of drought, that is, when the rainfall volume in the month prior to the month of research data collection is lower than the historical mean deviation, the results indicate a positive effect on employment (1.5%) and on the number of formal small-sized establishments (2.5%), and these impacts are stronger, in magnitude and significance, in the semi-arid region (2% and 4%, respectively). In addition, there was a positive effect of drought on the formal income of the semi-arid region, while the rain had had a negative impact.

The direction of drought impacts on labor market indicators can be explained based on the characteristics of employment in the Northeast and semi-arid Northeast as well as on the literature. One explanation, present in the literature, lies in the way workers adapt to climatic events and their different effects on sectors. Rainfall volume shocks are expected to have a stronger impact on sectors directly exposed to the weather, such as agriculture, in relation to the others, causing workers to migrate to jobs in less affected sectors. As agricultural work is mostly informal and workers seek other sectors where the level of formalization is higher, formal employment may increase. This increase, in turn, may explain the higher income during drought shocks, since this segment has, on average, higher remuneration compared to the informal sector.

Table 5 shows the impacts of climatic variables of the month prior to the data collection on sectoral employment in the formal labor market in the Northeast region.

It is possible to observe that the rainfall volume is positively related to employment in the agricultural sector, both in municipalities that are outside and in those that are in the semi-arid region, that is, an increase in the rainfall volume in the previous month increases the portion (%) of agricultural employment in 0.006 percentage point (PP) outside the semi-arid region and in 0.002 PP in the semi-arid region, and the opposite is true. On the other hand, when observing only the semi-arid sample, both the rainfall volume and the monthly deviation are negatively related to the trade and services sector (-0.008 PP and -20.4 PP). These results indicate that there may be mobility between sectors due to climatic shocks, given the direct effect that the rainfall volume has on the agricultural sector.

TABLE 5. **IMPACTS OF CLIMATIC VARIABLES OF THE PREVIOUS MONTH ON THE PORTION OF SECTORAL EMPLOYMENT IN THE FORMAL LABOR MARKET IN THE NORTHEAST REGION: 2002-2017**

Panel A: Outside the semi-arid region			
Period: 1 month	Agricultural/forestry/fishing	Services/trade	Industry
Rainfall volume	0.0064***	0.0024	-0.0001
	(0.0020)	(0.0020)	(0.0013)
Notes	11125	11125	11125
Monthly historical deviation	0.1180	-0.0356	0.0381
	(0.0909)	(0.1138)	(0.0668)
Notes	10795	10795	10795
Drought	-0.2480	0.1886	0.2260
	(0.2009)	(0.2792)	(0.1800)
Notes	11,140	11,140	11,140
Panel b: semi-arid region			
Period: 1 month	Agricultural/forestry/fishing	Services/trade	Industry
Rainfall volume	0.0022*	-0.0080***	0.0017
	(0.0012)	(0.0029)	(0.0019)
Notes	15,740	15,740	15,740
Monthly historical deviation	0.0296	-0.2045**	0.0790
	(0.0449)	(0.0971)	(0.0577)
Notes	15,250	15,250	15,250
Drought	-0.1075	0.1910	-0.2128
	(0.1220)	(0.2535)	(0.1598)
Notes	15,740	15,740	15,740
Socioeconomic	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes

Notes: the month precedes data collection; standard errors in parentheses; clustered errors at the municipal level; significance level: *p < 0.10, **p < 0.05, *** p < 0.01.

Source: Own elaboration.

In order to verify whether the effects of changes in the rainfall volume remain, considering a longer period of time, the econometric model was estimated using the following measures of climate change: rainfall deviation of the three and six months prior to the month of research data collection in relation to the rainfall historical mean of the same months (since the 1950s); and drought, that is, when the rainfall volume in the three and six months prior to the month of research data collection is lower than the historical mean deviation of the respective months.

Table 6 presents the impacts of these variables on employment and income in the formal labor market in the Northeast region. For the sample of municipalities that are outside the semi-arid region, the rainfall deviation in the last six months is positively related to income in the formal labor market (1.1%), a result similar to that found for one-month rainfall volume, while the drought occurrence in the last three months has a negative impact on this indicator (-1.2%). The rainfall deviation in relation to the historical mean in the last three and six months has a positive impact on formal employment outside the semi-arid region (1.6% and 5.6%, respectively), while drought has a negative impact (-3.7 % and -2.5%, respectively). These results indicate that when the rainfall shock extends over a longer period, it is possible that the reduction in the rainfall volume will negatively impact employment and income in the formal labor market.

TTABLE 6. **IMPACTS OF CLIMATIC VARIABLES OF THE PREVIOUS THREE AND SIX MONTHS ON EMPLOYMENT AND INCOME IN THE FORMAL LABOR MARKET IN THE NORTHEAST REGION: 2002-2017**

Panel A: All the municipalities				
Period: 3 and 6 months	Income	Employment	Hours	Small-sized establishments
3-month historical deviation	0.0003	0.0023	-0.0702	0.0077***
	(0.0024)	(0.0040)	(0.0446)	(0.0026)
Notes	26719	28497	26719	26584
6-month historical deviation	-0.0011	0.0338***	-0.0328	-0.0086**
	(0.0031)	(0.0063)	(0.0556)	(0.0042)
Notes	26,863	28,641	26,863	26,728
3-month drought	-0.0045	-0.0203***	0.1933**	-0.0102**
	(0.0040)	(0.0072)	(0.0780)	(0.0050)
Notes	26880	28659	26880	26745
6-month drought	0.0033	-0.0178**	-0.0197	0.0137***
	(0.0042)	(0.0080)	(0.0762)	(0.0049)
Notes	26,880	28,659	26,880	26,745
Panel B: Outside the semi-arid region				
Period: 3 and 6 months	Income	Employment	Hours	Small-sized establishments
3-month historical deviation	0,0020	0,0164**	0,0249	0,0253***
	(0,0039)	(0,0077)	(0,0654)	(0,0048)
Notes	11.056	11.789	11.056	10.990
6-month historical deviation	0,0110*	0,0565***	0,1425	-0,0109
	(0,0064)	(0,0133)	(0,1060)	(0,0086)
Notes	11.125	11.858	11.125	11.059
3-month drought	-0,0118**	-0,0375***	-0,0740	-0,0328***
	(0,0058)	(0,0125)	(0,0978)	(0,0075)
Notes	11.140	11.874	11.140	11.074
6-month drought	0,0002	-0,0247*	-0,1583	0,0113
	(0,0057)	(0,0127)	(0,0980)	(0,0079)
Notes	11.140	11.874	11.140	11.074

Panel C: Semi-arid region				
Period: 3 and 6 months	Income	Employment	Hours	Small-sized establishments
3-month historical deviation	0,0007	-0,0047	-0,1065*	-0,0012
	(0,0030)	(0,0043)	(0,0587)	(0,0031)
Notes	15.663	16.708	15.663	15.594
6-month historical deviation	-0,0018	0,0229***	-0,0785	-0,0064
	(0,0038)	(0,0066)	(0,0712)	(0,0046)
Notes	15738	16783	15738	15669
3-month drought	0,0015	-0,0070	0,4093***	0,0087
	(0,0054)	(0,0086)	(0,1132)	(0,0067)
Notes	15.740	16.785	15.740	15.671
6-month drought	0,0051	-0,0099	0,1235	0,0167***
	(0,0060)	(0,0100)	(0,1165)	(0,0064)
Notes	15.740	16.785	15.740	15.671
Socioeconomic	Yes	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes

Notes: the month precedes data collection; standard errors in parentheses; clustered errors at the municipal level; significance level: *p < 0.10, **p < 0.05, *** p < 0.01.

Source: Own elaboration.

The results for the semi-arid region show a positive and statistically significant relationship between rainfall deviation in the last six months and formal employment (2.3%), similar to the effect of one-month rainfall volume. The highest rainfall deviation in the last three months negatively affected the hours worked in the semi-arid region (-0.1065 average hours), a result similar to that found for the one-month deviation, while drought increased the number of hours worked (0.4093 average hours).

In turn, the historical deviation of the last three months positively affected the number of formal small-sized establishments outside the semi-arid region (2.5%), while drought reduced this indicator (-3.3%). However, for the semi-arid region, the results point to a positive relationship between drought occurrence in the last six months and the number of formal small-sized establishments (1.7%), similar to the result found for one-month drought, a result that may signal these municipalities' job offer adaptation to the climatic event.

Tables 7 and 8 show the impacts of climate variables on employment and income in the labor market as a whole, including the informal market, using 2000 and 2010 Censuses data. As in the previous tables, panel A presents the results for all municipalities in the Northeast; in panel B there are those for municipalities located outside the semi-arid region, and in panel C those for municipalities belonging to the semi-arid region. Result variables are: labor income, hours worked, self-employment, informal work, and urban employment.

TABLE 7. IMPACTS OF CLIMATIC VARIABLES OF THE PREVIOUS MONTH ON EMPLOYMENT AND INCOME IN THE LABOR MARKET IN THE NORTHEAST REGION: 2000 AND 2010

Panel A: All the municipalities					
Period: 1 month	Income	Hours	Self-employed	Informal	Urban employment
Rainfall volume	0,0002**	-0,0001	-0,0000	-0,0001**	-0,0001
	(0,0001)	(0,0011)	(0,0002)	(0,0001)	(0,0001)
Notes	3.551	3.551	3.515	3.515	3.491
Monthly historical deviation	0,0080	0,2148***	-0,0220**	-0,0043	0,0006
	(0,0049)	(0,0670)	(0,0105)	(0,0037)	(0,0053)
Notes	3.456	3.456	3.424	3.424	3.400
Drought	0,0362***	-0,3965**	-0,0391	-0,0143	-0,0166
	(0,0134)	(0,1811)	(0,0257)	(0,0110)	(0,0143)
Notes	3.553	3.553	3.517	3.517	3.491
Panel B: Outside the semi-arid region					
Period: 1 month	Income	Hours	Self-employed	Informal	Urban employment
Rainfall volume	0,0002*	-0,0019	-0,0001	-0,0001	-0,0001
	(0,0001)	(0,0015)	(0,0002)	(0,0001)	(0,0002)
Notes	1.470	1.470	1.446	1.446	1.425
Monthly historical deviation	0,0402***	0,2654**	-0,0522***	-0,0216***	-0,0130
	(0,0114)	(0,1340)	(0,0173)	(0,0076)	(0,0095)
Notes	1.464	1.464	1.440	1.440	1.419
Drought	0,0010	-0,4977	0,0512	0,0191	-0,0207
	(0,0234)	(0,3384)	(0,0382)	(0,0178)	(0,0233)
Notes	1.472	1.472	1.448	1.448	1.425
Panel C: Semi-arid region					
Period: 1 month	Income	Hours	Self-employed	Informal	Urban employment
Rainfall volume	0,0002	0,0036**	0,0002	-0,0001	-0,0000
	(0,0001)	(0,0017)	(0,0003)	(0,0001)	(0,0001)
Notes	2.081	2.081	2.069	2.069	2.066
Monthly historical deviation	0,0016	0,2068***	-0,0154	0,0030	0,0071
	(0,0056)	(0,0778)	(0,0132)	(0,0043)	(0,0065)
Notes	1.992	1.992	1.984	1.984	1.981
Drought	0,0389**	-0,3119	-0,0691*	-0,0290**	-0,0140
	(0,0173)	(0,2217)	(0,0356)	(0,0142)	(0,0185)
Notes	2.081	2.081	2.069	2.069	2.066
Socioeconomic	Yes	Yes	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes

Notes: the month precedes data collection; standard errors in parentheses; clustered errors at the municipal level; significance level: *p < 0.10, **p < 0.05, *** p < 0.01.

Source: Own elaboration.

TABLE 8. **IMPACTS OF CLIMATIC VARIABLES OF THE PREVIOUS THREE AND SIX MONTHS ON EMPLOYMENT AND INCOME IN THE LABOR MARKET IN THE NORTHEAST REGION: 2000 AND 2010**

Panel A: All the municipalities					
Period: 3 and 6 months	Income	Hours	Self-employed	Informal	Urban employment
3-month historical deviation	-0,0629***	-0,3007*	-0,0396	0,0098	0,0144
	(0,0126)	(0,1710)	(0,0270)	(0,0094)	(0,0131)
Notes	3.551	3.551	3.515	3.515	3.491
6-month historical deviation	0,0049	-0,3073	0,0946	0,0261	0,0456
	(0,0260)	(0,4200)	(0,0576)	(0,0222)	(0,0349)
Notes	3.551	3.551	3.515	3.515	3.491
3-month drought	0,1328***	0,2673	0,0701	0,0196	-0,0277
	(0,0301)	(0,4126)	(0,0632)	(0,0225)	(0,0260)
Notes	3.553	3.553	3.517	3.517	3.491
6-month drought	0,0558***	-0,7632***	-0,1004**	0,0162	0,0419
	(0,0181)	(0,2502)	(0,0421)	(0,0136)	(0,0288)
Notes	3.553	3.553	3.517	3.517	3.491
Panel B: Outside the semiarid region					
Period: 3 and 6 months	Income	Hours	Self-employed	Informal	Urban employment
3-month historical deviation	-0,0095	-0,3492	-0,0495	-0,0099	-0,0568
	(0,0363)	(0,4479)	(0,0501)	(0,0216)	(0,0450)
Notes	1.470	1.470	1.446	1.446	1.425
6-month historical deviation	-0,0122	-0,5724	0,1340	0,0369	0,0156
	(0,0474)	(0,7540)	(0,0885)	(0,0388)	(0,0877)
Notes	1.470	1.470	1.446	1.446	1.425
3-month drought	0,0883*	0,6762	0,0584	0,0449	-0,0057
	(0,0475)	(0,7924)	(0,0775)	(0,0368)	(0,0383)
Notes	1.472	1.472	1.448	1.448	1.425
6-month drought	0,0289	-0,9667***	-0,0009	0,0191	0,0239
	(0,0248)	(0,3584)	(0,0427)	(0,0200)	(0,0505)
Notes	1.472	1.472	1.448	1.448	1.425
Panel C: Semiarid region					
Period: 3 and 6 months	Income	Hours	Self-employed	Informal	Urban employment
3-month historical deviation	-0,0567***	-0,4172**	-0,0514	0,0126	0,0143
	(0,0145)	(0,1881)	(0,0316)	(0,0106)	(0,0141)
Notes	2.081	2.081	2.069	2.069	2.066
6-month historical deviation	0,0070	0,2281	0,0509	0,0129	0,0643
	(0,0340)	(0,5209)	(0,0764)	(0,0277)	(0,0397)
Notes	2.081	2.081	2.069	2.069	2.066
3-month drought	0,1331***	0,3284	0,0725	0,0024	-0,0027
	(0,0412)	(0,5283)	(0,0834)	(0,0276)	(0,0333)
Notes	2.081	2.081	2.069	2.069	2.066
6-month drought	0,0706**	-0,1891	-0,1658**	0,0253	0,0837***
	(0,0281)	(0,3568)	(0,0738)	(0,0180)	(0,0267)
Notes	2.081	2.081	2.069	2.069	2.066
Socioeconomic	Yes	Yes	Yes	Yes	Yes
Municipality fixed effect	Yes	Yes	Yes	Yes	Yes
Year fixed effect	Yes	Yes	Yes	Yes	Yes

Notes: the month precedes data collection; standard errors in parentheses; clustered errors at the municipal level; significance level: *p < 0.10, **p < 0.05, *** p < 0.01.

Source: Own elaboration.

Table 7 shows that the rainfall volume in the month prior to the month of the research caused a reduction in informal work (-0.01%) and an increase in labor income (0.02%) in the municipalities of the Northeast, and increased hours worked in the semi-arid region (0.36%). When analyzing the results for the Northeast and the municipalities that are outside the semi-arid region, it is possible to notice that rainfall historical deviation has a positive relationship with hours worked (increase of 0.215 and 0.265 in average hours, respectively), and negative with self-employment (-2.2% and -5.2%, respectively) and informal work (-2.2%, outside the semi-arid region), that is, negative deviation (less rain) is associated with reduced hours worked and increased self-employment and informal work in these areas. When analyzing only the semi-arid municipalities, the results show a positive relationship between the historical deviation and the hours worked (0.2068 in average hours), similar to the relationship found for the rainfall volume.

Regarding the drought variable, no statistically significant results were found for the sample of municipalities that are outside the semi-arid region. In turn, when analyzing the set of municipalities in the Northeast and those in the semi-arid region, the results indicate a positive relationship between drought and labor income (3.6% and 3.9%, respectively). For the municipalities in the Northeast, in general, drought had a negative impact on hours worked (-0.3965 average hours). On the other hand, drought occurrence in the month prior to the month of the research is associated with a reduction in self-employment (-6.9%) and informal work (-2.9%) in the semi-arid region. It is worth mentioning that drought, for the same period, positively affected formal employment in the semi-arid region, which seems compatible with the hypothesis of job reallocation between informal and formal segments during climate shocks.

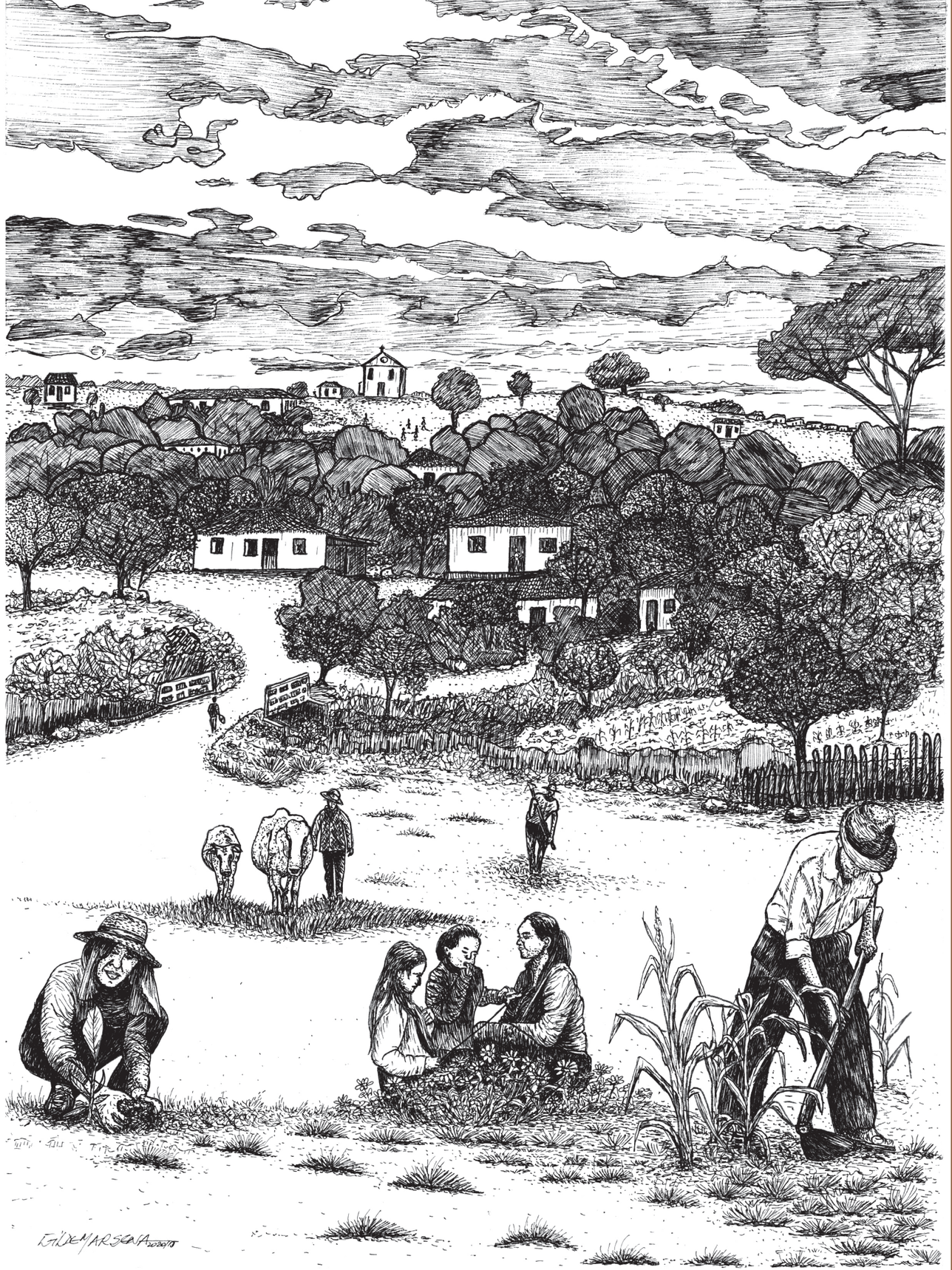
Table 8 presents the impacts of climatic variables in the three and six months prior to the data collection on employment, income, and hours worked. Similar patterns were found to those previously presented.

The results for the Northeast as a whole seem to be influenced mainly by the results of the semi-arid municipalities, since few parameters were statistically significant for the sample of municipalities that were outside the semi-arid region. The rainfall historical deviation over the last three months showed a negative relationship with labor income (-6.3% and -5.7%, respectively) and hours worked (-0.3007 and -0.4172 average hours, respectively), both for the Northeast and the semi-arid region.

In other words, a negative deviation (little rain) is associated with an increase in income and hours. The negative effects of the three-month deviation on income and hours worked in the semi-arid region were similar to the effects found for rainfall and the one-month deviation on the formal labor market.

Drought occurrence in the last three and six months immediately prior to data collection had a positive impact on labor income, both in the Northeast (13.3% and 5.6%, respectively) and in the semi-arid region (13.3% and 7, 06%, respectively), a result similar to that found for the one-month drought. Drought occurrence in the last six months, in turn, reduced the number of self-employment in both groups (-10% and -16.6%, respectively), with greater intensity for the semi-arid sample. In addition, for the sample of municipalities in the semi-arid region, drought occurrence in the last six months increased urban work (8.4%).

In Tables 7 and 8, it is possible to see that the impact of climatic variables on labor market indicators is different when the location of municipalities in the Northeast region is considered. In municipalities that are outside the semi-arid region, the rainfall deviation of the previous month in relation to the historical mean, when negative (less rain) is associated with decreased labor income, increased self-employment, and increased informal work. In the case of semi-arid municipalities, drought occurrence (which is also characterized by scarcity of rain, although using another metric) is associated with increased income, decreased self-employment, and decreased informal work.



5.Discussion and conclusion

The aim of this study was to analyze the impacts of extreme weather events on work and income in the Northeast and the semi-arid region. Data from the 2010 Demographic Census (IBGE), for the regional labor markets in Brazil, showed that the Northeast and the semi-arid Northeast region were characterized by a labor market with a large portion of informal jobs and high unemployment and agricultural sector employment. The unemployment and participation rates (economically active portion in the working-age population) are lower in the semi-arid Northeast. The lower unemployment rate in the semi-arid region can be explained by the greater composition of employment among informal and self-employed occupations, which absorb a portion of workers who could be unemployed. The costs of greater informality in the semi-arid region can be measured from the lowest average remuneration in this segment and the absence of coverage in relation to the labor benefits associated with formal employment (statutory employment or employee working on the books).

In summary, the results found suggest that drought occurrence increases formal employment in the municipalities (1.5% in the Northeast and 2% in the semi-arid region), which can be seen in Table 4. This result suggests that individuals migrate from activity in the countryside to formal activity in the urban zone when extreme weather events occur. That is, given the difficulties encountered by the lack of rain, individuals seek other sources of income to support their families. The semi-arid Northeast is heavily dependent on informal and family farming activities that make the elaboration of public policies aimed at the labor market a more difficult task due to the local specificities. This evidence is corroborated by the fact that informal employment reduces by 2.9% when droughts occur, as seen in Table 7.

In this sense, policies to guarantee the conditions for the development of agricultural activities in the face of the most likely climatic shocks are paramount for the maintenance of workers in the rural area without implying severe losses of income. This involves both regular and sustainable access to water policies and technical assistance to professionalize agricultural activities, as well as assistance and credit during shocks. However, due to the nature of the data available, the study has the limitation of not being able to advance in the understanding of the reasons why individuals migrate to formal activities and are unable to remain in the field, even with the recent advance of public policies in the region.

To estimate the impacts on the labor market, three climate indicators were analyzed: (1) rainfall volume; (2) rainfall deviation in relation to its historical mean (since 1950); and (3) drought indicator (rainfall volume below the mean historical deviation). The results showed that drought positively impacts the number of jobs and formal small-sized establishments and income, while negatively affecting informal work and self-employment. The results were more intense in the semi-arid region. In turn, the rainfall volume and its deviation lead to decrease of hours worked and income in the formal work in the semi-arid region, while increasing hours in the total labor market (formal and informal). The evidence found in this report suggests that there is a job reallocation between formal and informal segments, at the municipal level, which occurs more intensely in the semi-arid region. Mobility between sectors, resulting from climate shocks, may also explain part of the results found.

The results found in this study corroborate the national and international evidence of the impacts of the climate and, in particular, of droughts on the population's work and income. Regarding the impact of drought on formal employment, it is possible to highlight the work of Ayenew (2017). From panel data, for 2001 and 2004, of rural families involved in agricultural activities in Mozambique, the results found indicate that there is a significant job offer adaptation during and after episodes of positive and negative rainfall shocks, with negative (drought) shocks related to greater involvement in salaried non-agricultural activities. In other words, the fact that negative shocks in the rainfall volume impact the agricultural sector more strongly than the others makes workers migrate to jobs in less affected sectors. In addition, the work found evidence that positive rainfall shocks increase self-employment, particularly in trade services and in micro and small businesses.

Agricultural work is mostly informal, family or self-employed, especially in rural areas of the semi-arid region. In this sense, the fact that workers seek other sectors, in which the level of formalization is higher, may contribute to the increase in formal employment when the aggregate municipal results are analyzed. The results described in Table 5 corroborate the understanding that a reduction in the rainfall volume is associated with a fall in agricultural employment and an increase in employment in trade and services sectors. In view of this, the positive relationship between drought, employment and income, in the formal segment of the labor market, can be explained by the search for non-agricultural activities (most likely to be formalized) in periods of low rainfall. In addition, as formal jobs are associated with higher average wages, this would explain the increased income as a result of negative rainfall shocks.

The results found through the census database (formal and informal) follow the same pattern, in which drought has a positive influence on labor income and a negative influence on informal work and self-employment, when analyzing the semi-arid municipalities, evidence that dialogs with that found in the study by Branco and Feres (2018). In the study carried out for rural families in the Northeast region, the authors find evidence that water scarcity is associated with lower income derived from the main work, whether agricultural or not, and with higher income derived from secondary jobs.

In addition, drought shocks are associated with a greater probability of having more than one job, a lesser portion of agricultural work in total hours worked and a greater portion of secondary jobs in total hours. These results proved to be even stronger for the municipalities whose per capita income was lower.

In this way, the results found are in line with the studies by Ayenew (2017) and Branco and Feres (2018), since the semi-arid region concentrates the municipalities with the lowest per capita income in the Northeast region, where drought reduces informal work and self-employment, which generally have a lower average income than formal work, while formal work increases, given the search for workers in sectors less affected by climate shocks, such as trade and services. The implications of these results in terms of public policies for the labor market in the Northeast and in the semi-arid Northeast are diverse and can contribute to improving the understanding of the insertion of the population in local productive activities.

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Appendices

CHART A. 1. CONTROL VARIABLES FOR RESULT INDICATORS OF THE LABOR MARKET

Control Variable	Description	Source
Indicator Labor income (RAIS; Census)		
Municipal GDP	Municipality's GDP (in thousand reais)	IBGE
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	RAIS/Census
Gender	Proportion of female workers in the municipality	RAIS/Census
Race	Proportion of workers per level of education in the municipality	Proportion of black and brown workers in the municipality
Experience	Average length of time at a job (in months in the same job) of workers in the municipality	RAIS
Age	Average age/age group of workers in the municipality	RAIS/Census
Size of formal establishment: • Small-sized establishment (up to 99 employees) • Middle-sized establishment (100 to 499) • Large-sized establishment (500 +)	Proportion of establishments per size in the municipality, defined by the number of employees	RAIS
Sectorial Employment: • Industry • Trade and services • Agricultural	Proportion of jobs per major sector in the municipality	RAIS (IBGE Sector)/ Census (CNAE Domiciliar)
Occupation groups: • Classification of Occupations for Household Surveys • Brazilian Classification of Occupations	Proportion of jobs per occupation group in the municipality	RAIS (CBO 2002) /
Public sector employment	Proportion of jobs in public administration in the municipality	RAIS/Census
Formality	Proportion of workers contributing to an official social security institute in some work in the municipality	Proportion of black and brown workers in the municipality
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

Indicator: Hours worked (RAIS; Census)		
Municipal per capita GDP	Municipality's GDP per capita	IBGE
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	RAIS/Census
Gender	Proportion of female workers in the municipality	RAIS/Census
Race	Proportion of workers per level of education in the municipality	Proportion of black and brown workers in the municipality
Experience	Average length of time at a job (in months in the same job) of workers in the municipality	RAIS
Age	Average age/age group of workers in the municipality	RAIS/Census
Family heads	Proportion of workers who were responsible for the household in the municipality	Census
Average number of children per woman	Ratio between the number of live children and women aged 10 and over who had children	Census
Size of formal establishment: • Small-sized establishment (up to 99 employees) • Middle-sized establishment (100 to 499) • Large-sized establishment (500 +)	Proportion of establishments per size (in number of employees) in the municipality	RAIS
Sectorial Employment: • Industry • Trade and services • Agricultural	Proportion of jobs per major sector in the municipality	RAIS (IBGE Sector)/ Census (CNAE Domiciliar)
Occupation groups: • Classification of Occupations for Household Surveys • Brazilian Classification of Occupations	Proportion of jobs per occupation group in the municipality	RAIS (CBO 2002)/
Public sector employment	Proportion of jobs in public administration in the municipality	RAIS/Census
Formality	Proportion of workers contributing to an official social security institute in some work in the municipality	Census
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

Indicator: Number of small-sized establishments (up to 49 employees)		
Municipal GDP	Municipality's GDP (in thousand reais)	IBGE
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	RAIS
Gender	Proportion of female workers in the municipality	RAIS
Experience	Average length of time at a job (in months in the same job) of workers in the municipality	RAIS
Age	Average age/age group of workers in the municipality	RAIS
Sectorial Employment: • Industry • Trade and services • Agricultural	Proportion of jobs per major sector in the municipality	RAIS (IBGE Sector)
Occupation groups: • Brazilian Classification of Occupations	Proportion of jobs per occupation group in the municipality	RAIS (CBO 2002)
Public sector employment	Proportion of jobs in public administration in the municipality	RAIS
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census
Indicator: Number of formal jobs (RAIS)		
Municipal per capita GDP	Municipality's GDP per capita	IBGE
Size of formal establishment: • Small-sized establishment (up to 99 employees) • Middle-sized establishment (100 to 499) • Large-sized establishment (500 +)	Proportion of establishments per size (in number of employees) in the municipality	RAIS
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

Indicator: Number of self-employed workers (Census)		
Municipal GDP	Municipality's GDP (in thousand reais)	IBGE
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	Census
Gender	Proportion of female workers in the municipality	Census
Race	Proportion of workers per level of education in the municipality	Census
Family heads	Proportion of workers who were responsible for the household in the municipality	Census
Average number of children per woman	Ratio between the number of live children and women aged 10 and over who had children	Census
Age	Age group of workers in the municipality	Census
Sectorial Employment: • Industry • Trade and services • Agricultural sector	Proportion of jobs per major sector in the municipality	Census (CNAE Domiciliar)
Occupation groups: • Classification of Occupations for Household Surveys	Proportion of jobs per occupation group in the municipality	Census (COD)
Formal establishments	Number of formal establishments in the municipality	RAIS
Unemployment rate	Unemployment rate in the municipality	Census
Urban residents	Proportion of workers residing in the urban area of the municipality	Census
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

Indicator: Number of informal workers (Census)		
Municipal GDP	Municipality's GDP (in thousand reais)	IBGE
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	Census
Gender	Proportion of female workers in the municipality	Census
Race	Proportion of workers per level of education in the municipality	Census
Family heads	Proportion of workers who were responsible for the household in the municipality	Census
Average number of children per woman	Ratio between the number of live children and women aged 10 and over who had children	Census
Age	Age group of workers in the municipality	Census
Sectorial Employment: • Industry • Trade and services • Agricultural	Proportion of jobs per major sector in the municipality	Census (CNAE Domiciliar)
Occupation groups: • Classification of Occupations for Household Surveys	Proportion of jobs per occupation group in the municipality	Census (COD)
Formal establishments	Number of formal establishments in the municipality	RAIS
Unemployment rate	Unemployment rate in the municipality	Census
Urban residents	Proportion of workers residing in the urban area of the municipality	Census
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

Indicator: Number of workers in the urban area (Census)		
Municipal sectorial VAB • Industry • Services • Agricultural	Portion (%) of Gross Value Added by sector in the municipality	IBGE
Urban-rural income ratio	Ratio between average labor income in urban and rural areas of the municipality	Census
Level of Education • No Education (%) • Incomplete Primary Education • Elementary Education • Incomplete High School • High School • Incomplete Higher Education • Higher Education	Proportion of workers per level of education in the municipality	Census
Gender	Proportion of female workers in the municipality	Census
Race	Proportion of workers per level of education in the municipality	Census
Family heads	Proportion of workers who were responsible for the household in the municipality	Census
Average number of children per woman	Ratio between the number of live children and women aged 10 and over who had children	Census
Age	Age group of workers in the municipality	Census
Sectorial Employment: • Industry • Trade and services • Agricultural	Proportion of jobs per major sector in the municipality	Census (CNAE Domiciliar)
Occupation groups: • Classification of Occupations for Household Surveys	Proportion of jobs per occupation group in the municipality	Census (COD)
Formal establishments	Number of formal establishments in the municipality	RAIS
Rural unemployment rate	Unemployment rate among rural residents in the municipality	Census
Population density	Ratio between population and area (km2) of the municipality	IBGE/Census

CNAE Domiciliar: comes from the National Classification of Economic Activities and it is used in the demographic census and others household surveys; CBO: Brazilian Classification of Occupations Classification of Occupations for Household Surveys

Note: the small establishment will be classified in two ways based on Sebrae (2018): the classification of the trade and services sector (up to 49 employees) was adopted for the number of small-sized establishments, used as a dependent variable in one of the models; the classification of the industrial sector (up to 99 employees) was adopted for the portion of small-sized establishments, used as an explanatory variable in some models.

Source: Own elaboration.

CHART A. 2. REFERENCE CATEGORIES FOR THE CATEGORICAL VARIABLES OF THE MODELS

Variable	Classification	Reference	Source
Level of Education	No education and incomplete primary education Primary education and incomplete high school High school and incomplete higher education Higher Education	No education and incomplete primary education	RAIS/ Census
Gender	Male Female	Male	RAIS/ Census
Race	White Black and brown Other (Asian, indigenous people, and non-declared)	White and others	Census
Age group	10-14 years old 15-29 years old 30-59 years old 60+	30-59 years old	Census
Formal establishment's size:	Small-sized establishment (up to 99 employees) Middle-sized establishment (100 to 499) Large-sized establishment (500 +)	Small-sized establishment (up to 99 employees)	RAIS
Sectoral employment of CNAE Domiciliar	Industry Trade Services Agricultural sector Other sectors (fishing, electricity, gas and water, construction, public administration, international organizations and ill-defined sectors)	Other sectors (%)	Census
Employment per sector (IBGE Sector)	Industry (mining and manufacturing) Trade Services Agricultural, plant extraction, hunting and fishing sectors Other sectors (industrial utilities, civil construction and public administration)	Other sectors (%)	RAIS
Occupational Groups of the Classification of Occupations for Household Surveys (COD)	Leaders and managers Science and arts Professional with technical high school degree Services and trade Agricultural, hunting and fishing sectors Industry Other occupations (repair and maintenance, police, armed forces and firefighters, and ill-defined occupations)	Other occupations	Census
Occupation groups of Brazilian Classification of Occupations(CBO 2002 – Large group)	Leaders and managers Science and arts Professional with Technical High School degree Services and trade Agriculture and livestock, hunting and fishing Industry Other occupations (repair and maintenance and not classified)	Other occupations	RAIS

Source: Own elaboration.

List of acronyms

ASA	Brazilian Semi-arid Articulation
CBO	Brazilian Classification of Occupations
CNAE	National Classification of Economic Activities
COD	Classification of Occupations for Household Surveys
CPS	Current Population Survey
IFAD	International Fund for Agricultural Development
IBGE	Brazilian Institute of Geography and Statistics
IPCA	Broad National Consumer Price Index
ME	Ministry of Economics
UN	United Nations
PEA	Economically Active Population
PIA	Working Age Population
PIB	Gross National Product
PNAD	National Household Sample Survey
RAIS	Annual List of Social Information
UFBA	Federal University of Bahia
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund

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