UNIVERSIDADE FEDERAL DO RIO DE JANEIRO

INSTITUTO DE ECONOMIA

PROGRAMA DE PÓS-GRADUAÇÃO EM ECONOMIA

NATHALIA MACHADO SALES

ENVIRONMENTAL DISASTERS: ECONOMIC AND HEALTH OUTCOMES

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Dissertação de Mestrado apresentada ao Programa de Pós-Graduação em Economia (PPGE) do Instituto de Economia da Universidade Federal do Rio de Janeiro, como parte dos requisitos necessários à obtenção do título de Mestre em Ciências Econômicas.

Orientador: Dr. Romero Cavalcanti Barreto da Rocha

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Aprovada em Rio de Janeiro, 13 de março de 2020.

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ABSTRACT

In November of 2015, the failure of a mining tailing dam located in Mariana (MG) led to one of the largest socio-environmental disasters in the history of Brazil. The disaster impacted the environment and the population from the basin of Rio Doce River in a way not completely understood yet. Rigorously documenting these impacts is fundamental to guide discussions on the regulation of dams and on the compensation measures for the affected populations. In this context, this dissertation uses a differences-in-differences framework to evaluate the effects of the Mariana disaster on health and economic outcomes. Using administrative data from Department of Informatics of the Brazilian Unified Health System (DATASUS), we estimate the impact of the disaster on health at birth, infant mortality, and hospitalization rates. In addition, we explore data from the Brazilian Institute of Geography and Statistics (IBGE), to estimate the impact of the disaster on local economic indicators. Concerning health outcomes, we find a positive significant impact on neonatal infant mortality (+9,3%) and hospitalizations due to skin diseases (+12%). On the other side, we find a negative impact on municipal GDP (-5,4%), which is driven by a reduction in the output of the manufacturing sector (-13,8%), and on aquaculture production value (-5,9%).

Keywords: environmental disasters; health at birth; infant mortality, hospitalization; local economy

RESUMO

Em novembro de 2015, o rompimento de uma barragem de rejeitos de mineração, localizada em Mariana (MG), ocasionou um dos maiores desastres socioambientais no Brasil. O desastre impactou o meio ambiente e a população ao redor do Rio Doce de maneira ainda não completamente compreendida. A documentação rigorosa desses impactos é fundamental para orientar as discussões sobre a regulação de barragens e as medidas de compensação para a população afetada. Nesse contexto, esta dissertação utiliza um modelo de diferenças em diferenças para avaliar os efeitos do desastre de Mariana em indicadores econômicos e de saúde. Utilizando dados administrativos do Departamento de Informática do Sistema Único de Saúde (DATASUS), estimamos o impacto do desastre em alguns indicadores de saúde ao nascer, mortalidade infantil e taxa de hospitalização. Além disso, exploramos dados do Instituto Brasileiro de Geografia e Estatística (IBGE), para estimar o impacto do desastre em alguns indicadores da economia local. Em relação à saúde, encontramos um impacto positivo significativo na mortalidade infantil neonatal (+9,3%), e em internações por doenças de pele (+12%). Já em relação à economia local, encontramos um impacto negativo sobre o PIB municipal (-5,4%), impulsionado por uma redução na produção do setor manufatureiro (-13,8%), e sobre o valor da produção da aquicultura (-5,9%).

Palavras chave: desastres ambientais; saúde ao nascer; mortalidade infantil, internação; economia local

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1. Introduction

In many developing countries, mining plays a fundamental role for local economic performance and is an important source of government revenues. For instance, in 2018, Brazil has exported more than 409 billion tons of mineral goods, adding up to US$ FOB 29,9 billion. The amount represents 12,5% of Brazil total exports. The mining extractive industry has also an important participation on the gross domestic product, representing around 1,4% of Brazil's GDP (IBRAM, 2019).

This scenario usually engenders a debate about an old trade-off between growth and sustainable development, and how this sector should be regulated to minimize its environmental impacts, such as tailings dam disasters, like those which happened in two Brazilian cities from the state of Minas Gerais (Mariana in 2015 and Brumadinho in 2019). Although this discussion will not be our focus here, it is important to realize that unlike natural disasters, tailings dam failures are usually preventable and mainly occur due to a poor regulatory enforcement.

In November of 2015, the city of Mariana, in Minas Gerais State, has experienced a huge mining dam breakage. The collapse of Fundão dam caused one of the Brazilian biggest socio-environmental disaster registered to date in Brazil. The disaster was classified as four- degree [1] by Civil Defense classification. On that moment, around 45 million cubic meters of mining tailing were dumped in "Gualaxo do Norte" River and then on "Rio Doce" River, traveling more than 600km until reaching the coast of the state of Espírito Santo (IBAMA, 2015).

The disaster has caused immediately a set of negative externalities, which brings significant consequences in the short, medium, and long run. Besides the nineteen deaths and thousands of homeless people, the disaster left huge damages on the environment. When the mud of tailing reached the river, the mineral concentrations on water has stood above the limits recommended by the Ministry of Health (Hatje et al., 2017). Additionally, the wave of mud has moved substances present in the riverbeds, carrying gold mining residues, pesticides and other residues accumulated in centuries of economic exploration. Also, the mud carried industrial effluents and domestic sewage, especially in areas with great urban concentration and industrial activity.

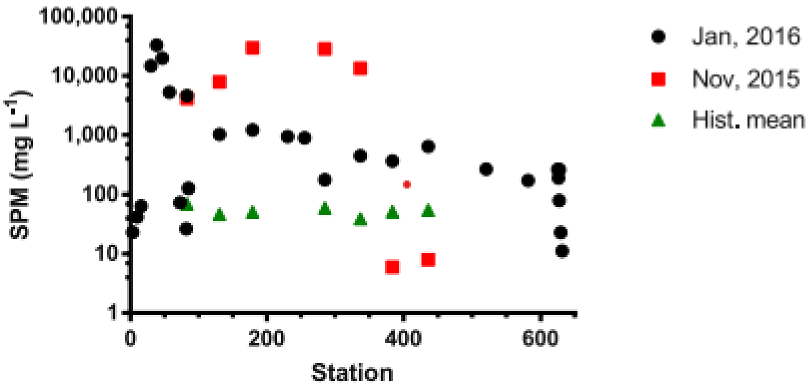
[1] Disasters of this type yield damage and loss that cannot be overcome independently by affected communities, requiring state and federal resources available in National Civil Defense System.

Therefore, rigorously evaluating the impact of this disaster is fundamental to understand the consequences of exposure to this disaster. This is important not only to evaluate the tradeoffs involved growth in mining activities but also to guide policymakers involved in the design of mining regulations and compensation schemes. Using a difference-in-differences approach, we investigate the causal effect of the Mariana disaster on health and economic outcomes on municipal level.

Historically, the mining activity can be considered as one of the main sources of watersheds pollution, what can generate serious implications for human health and for the biodiversity of these watersheds. However, what differs a disaster of a mining tailing dam to the usual disposition of metals, is the quantity and the speed which these tailings spread, covering soil, settling rivers, compromising the water quality and the local biome (Hatje et al., 2017).

As we can see in figure 1, although the transport, dilution and sedimentation process which affected the distribution and concentration of the tailing mud, three months after the dam breakage the concentration of suspended particulate matter was still significant. According to Hatje et al. (2017), this concentration was twice the historical mean.

Figure 1: Distribution of suspended particulate matter



Source: Hatje et. al. (2017)

From an economic perspective, water pollution led to interruption of many rivers dependent activities, compromising municipalities' tax revenues, once hydrological resources of Rio Doce River provide water for domestic use, livestock, farming, industrial production and energy generation of all region, apart from being a source of local fishing (ANA, 2016). In some municipalities, there was suspension of water supply due to water contamination by heavy metals and other components.

From a health perspective, there is evidence that the mining tailings might have impacted the health of local population residing in these municipalities, both because of direct effects like water pollution and atmospheric pollution (dry mud, mainly in near cities), but also because of indirect effects, by compromising the income of many families. Investigations made in Barra Longa, a neighboring municipality of Mariana, revealed multiples notifications about health problems in the post disaster period, such as more incidence of parasitic diseases, diarrhea, gastroenteritis, dermatitis, respiratory diseases, anxiety, hypertension, diabetes and dengue (Vormittag, Oliveira and Gleriano 2018).

To summarize, the disaster has impacted the environment and the population around the Rio Doce River basin in a way not completely understood yet. In a context of poverty and lack of access to financial mechanisms, these shocks might have serious consequences for well-being both in short run and long run. In this way, this work sheds light and contributes for the understanding of the disaster impact looking at two important aspects in development field: health and economic outcomes. As Carrillo et al. (2019) points, such estimates are crucial for the optimal design of environmental policies, and for evaluating the overall welfare impacts of mineral production in developing countries.

On the local economy side, we evaluate the impact on municipal gross domestic product, on aquaculture production value and on agriculture production value. Our results suggest a negative impact on municipal gross domestic product (-5,4%), especially in industrial sector (-13,8%), and also on aquaculture production value (-5,9%). From the health perspective, we evaluate the impact on birth outcomes – such as proportion of newborns with low weight, proportion of premature newborns and proportion of newborns with congenital anomaly – on infant mortality rate and on hospitalization due to specifics diseases. These indicators might reflect potential impacts on local population vulnerabilities and demand for public health system. In this context, we find a positive significant impact on neonatal infant mortality (+9,3%) and hospitalizations due to skin diseases (+12%).

There is a growing literature investigating the effects of the Mariana disaster. Carrillo et al., (2019) and Mrejen, Parelman and Machado, (2019) evaluate the impact of Mariana tragedy on health, but with some methodological differences and completely focused on health at birth. None of them investigate neonatal infant mortality neither hospitalization rates, for example. Furthermore, Castro and Almeida (2019) and Niquito et al. (2019) evaluate the disaster's impact on economy. However, besides methodology differences, our analysis goes further once we evaluate indicators related to aquaculture and agriculture.

The dissertation is structured as follows: Section 2 reviews the literature on environmental disasters and industrial pollution on health outcomes and on economic activity. Section 3 contains data explanation and descriptive statistics. Section 4 presents our empirical strategy. Section 5 presents and interprets the results. Section 6 contains some robustness checks. Finally, Section 7 summarizes the topic with final remarks.

2. Related Literature

In the last years, there has been an explosion of academic research about disasters consequences, especially about natural disasters. Although the Mariana dam breakage is considered a technical disaster, we can drive some insights of this literature. This 'new' interest can be assigned in first place to the growing awareness about the potentially catastrophic nature of these events and also to the growing awareness that disasters are social and economic events: their impact is molded both by event characteristics and by structure of impacted places (Karim and Noy, 2013).

Baez, de la Fuente and Santos (2013) points three main characteristics about disasters. First, and obviously, disasters are the opposite of human development. They bring substantial damage with loss of human and physical assets. However, even when there is no mortality, disasters bring potentially huge consequences to nutrition, education, health and income generation. Second, disasters do not affect people equally. There exists a high degree of heterogeneity on the impacts, which varies across different socioeconomic groups. Inequalities in risk exposure, in risk sensibility, in access to resources and opportunities, place part of the population in disadvantaged position. Third, although disasters are unexpected, there is an ample scope for policies both to prevent their occurrence and to mitigate their impacts.

The literature on the consequences of disasters is extensive, with evaluations going from the impact on economic growth in the short and medium run to evaluations about their effect on migration, fertility choices, human capital, poverty and income distribution (Karim and Noy, 2013). In general, the studies can be clustered in two research areas. The first one investigates microeconomic and social consequences of disasters. The second one explores the macroeconomic effects. In this context, this work is more aligned with the first strand of the literature. Below we present some literature insights on points related to local economic activity and health outcomes.

2.1. Disasters and Local Economy

In general, there is a literature consensus that natural disasters have, on average, negative impacts on economic activity in the sort run (Cavallo and Noy, 2009), although some find mixed effects. On the microeconomic field, some studies have been done is this sense. Leiter et al (2009) evaluate the impact of floods on firms' capital stock, employment and productivity in Europe and find mixed effects on capital stocks, positive effects on employment in the short run but negative productivity effects. Similarly, Strobl (2008) evaluates the impact of a volcano in the coast of United States and find that the most affected regions faced a decrease of 0,8% in their economic growth in the short run.

In Brazil, Ribeiro et al. (2014) apply a synthetic control technique to study the impact of a large flood in Santa Catarina state, in 2008, on industrial output. The adoption of industrial output as dependent variable stands like a monthly proxy for gross domestic product once this measure does not have a monthly frequency for Brazilian states. The estimated results show that industrial production was, on average, at least 5,13% lower after the flood then it would be in the lack of it.

Until now, there are few papers which evaluates Mariana's tragedy. To the best of our knowledge, the first attempt to show light to the economic consequences of the dam failure is Simonato (2018). This work develops a dynamic computable general equilibrium model to forecast the regional economic effects of the disaster between 2016 and 2020. According to the author, the period of five years showed up insufficient to retake the levels of production, family consumption, employment, and investment, even with the hypothesis of total resumption of mining activity in Mariana from 2018. Moreover, results suggest a strong interdependence of Rio Doce River regions in absorbing negative impacts.

Another paper that is especially interest for our work, is Castro and Almeida (2019). The authors use synthetic control to evaluate the impact of Mariana's disaster on the economic activity of Minas Gerais and Espírito Santo states. As stated in the results, in general, only the economy of Espírito Santo state was truly negatively impacted. Regarding the mineral extractive sector, both states were impacted, being Espírito Santo the most. The hypotheses presented by them is that the higher negative impact on Espírito Santo is due to a heavier sector dependence of this state, once mineral extractive has a great weight on Espírito Santo GDP – almost four times when compared to Minas Gerais GDP.

To finish, a paper with similar goals is Niquito et al. (2019), which make an analysis of the short run economic impacts of the Fundão dam failure on production and employment through a difference in differences model with spatial lags. The results point towards a negative impact on GDP (-6,94%), on industrial value added (-18,66%) and also on industrial employment (-372 formal job places, on average).

The present study, when evaluating the effect of the dam rupture on production variables, contributes to the literature on how technological and environmental disasters affect developing economies and advances over existing work. Differently from Castro and Almeida (2019) and similar to Niquito et al. (2019), our analysis allows to estimate the effects in a municipal level. Yet, this research uses a difference in differences model without spatial lags, differently than used by Niquito et al. (2019), and advances estimating the impact on aquaculture and agriculture production value.

2.2. Disasters and Health

As it was mentioned before, Mariana tragedy left a huge passive in terms of industrial pollution with the toxic mud released by the collapse of the Fundão dam flooding cities around the dam and contaminating the basin of the Rio Doce River. Thus, it is possible that the effects of the disaster on population health might be happened due to the pollution exposure. On the other side, there was a disruption in some economic activities related to mining and also river dependent activities. Thereby, another possibility is that health might have been deteriorated by an income effect (Brenner and Mooney, 1983; Wang and Halliday, 2017).

Investigations about the social costs of environmental pollution and its negative effects on human health have been gaining space in the economics literature. A high concentration of pollution may lead an individual make a higher use of medicines and visit hospital units more times (Graff Zivin and Neidell, 2013), beyond rising the likelihood of incidence of some diseases (Ebenstein, 2012; Rabbani, Chowdhury and Khan, 2009). Also, there are evidences that pollution might have negative consequences on labor supply (Hanna and Oliva, 2011) and labor productivity (Graff Zivin and Neidell, 2012) through health effects.

Moreover, a large body of economic research focus on the impact of environmental pollution on birth outcomes, in general, and low birthweight in particular. This interest is guided by the fact that low birthweight portrays an important risk factor for infant morbid mortality. The lower the birth weight, the higher is the possibility to premature death. Additionally, health at birth is frequently seen as an important predictor of scholar outcomes and returns on the labor market (Almond and Currie, 2011; Black., Devereux and Salvanes, 2007).

In that context, some studies have been done. Currie et al. (2013) evaluated the effect of in utero exposure to contaminated water in New Jersey, using a panel data between 1997 and 2007. The authors reached the conclusion that, to mothers with a low degree of schooling, who lived in districts with high water pollution during pregnancy, has been an increase of 14,55% in the incidence of low birth weight of newborns. Other studies in the same direction, such as Currie and Neidell (2005) and Currie, Neidell and Schmeider (2009), found that air pollution have negative effects on newborn health, measuring by incidence of low birth weight newborns and prematurity.

For Brazil, related analysis was made by Oliveira and Quintana-Domeque (2016), which evaluated the impact of in utero exposure to Catarina Hurricane in 2014, finding negative effect on birth weight and positive effect on likelihood of born with low birth weight; and by Rocha and Soares (2012), which evaluated the impact of in utero exposure to water scarcity in semiarid, finding that these shocks are strongly correlated with a lower birth weight and higher infant mortality. This last one, for its turn, is another important outcome usually present in development literature. By specifying the number of children who are not expected to survive the first year of life in every thousand live births, the infant mortality rate is one of the best indicators of local quality of life and social well-being.

Notwithstanding the environmental impact, both outcomes reflect socioeconomic conditions, as well as access and quality of available resources for maternal and childcare. In this context, negative income shocks play an important role (Bhalotra, 2010; Bozzoli and Quintana-Domeque, 2014). Regarding birth outcomes there is also a third mechanism, that is maternal stress, especially in moments close to the event (Bussieres et al., 2015; Camacho, 2008).

To date, there are only two studies which measure the impact of Fundão dam failure on health outcomes. The first one is Carillo et al. (2019), who exploit in utero exposure to the disaster. Through a difference in differences model, they construct a comparison group based on a hypothetical mud path - simulation of failure of other dams located in the same state[2] and built in the same years. The treatment is women living in municipalities affected by the disaster during their pregnancy. They find that being exposed to the disaster during pregnancy is associated with significantly reduced birth weight – around 23 grams – although no impact is found on gestational length, and significantly increase in infant mortality. In addition, the adverse effects were stronger for infants born to less educated and single mothers.

The second paper is Mrejen, Parelman and Machado (2019), which also evaluate the effect of Mariana's disaster on birth outcomes through difference in differences. They found that being directly exposed in utero to the tragedy resulted in shorter gestational age and 2,6 percentage points increase in incidence of preterm birth, especially in the first three months of gestation.

In this context the present study provides one more contribution to the literature on how technological and environmental disasters affect health and advances over existing work related to Mariana disaster. This research is significantly different from Carrillo et al. (2019) on treatment and control group specification and also, we do not make use of in utero analysis when estimating infant health effects. In relation to Mrejen, Parelman and Machado (2019), our analysis uses similar treatment and control groups, but they also capture in utero effects, which was not our focus. Besides that, we go further analyzing other outcomes, among them, infant mortality by specific causes and neonatal infant mortality, none of them estimated before. Also, we extend the research beyond infant health, looking for potential effects on hospitalization rate due to some diseases.

[2] They use only Minas Gerais municipalities.

3. Data

The treatment variable was constructed by public data provided by Renova Foundation – the institution responsible for guiding programs of repair, restauration and reconstruction of municipalities impacted by Fundão dam breakage. According to Renova Foundation there were 45 municipalities affected by the disaster, 35 in Minas Gerais and 9 in Espírito Santo state.[3]

3.1. Health Outcomes

All health outcomes were provided by Brazilian Health Informatics Department (DataSus). We constructed a dataset on health at birth and infant mortality combining microdata from the Brazilian National Birth Records System (Datasus/SINASC) and the Brazilian National Mortality Information System (Datasus/SIM).

The first database records every registered birth in Brazil and provides information on birth weight, length of gestation and newborns with congenital anomaly. The database also provides the exact date of birth, the municipality of birth, and the municipality of residence of the mother. This information allows us to construct a municipality-by-month of birth panel over the 2010-2017 period containing information on number of births, average birth weight, proportion of newborns with low weight (less than 2500 grams), proportion of preterm newborns and proportion of newborns with congenital anomaly. The municipality of reference in the panel is the municipality of residence of the mother. This is important because municipality of birth may be related to the availability of medical facilities in a given area – ex: mothers travel across municipalities to give birth in a hospital. In order to have better information, we dropped all births which happened out of hospitals or health facilities.

The Mortality Information System (DataSus/SIM), for your turn, provides information on every death officially registered in Brazil. It contains data on cause of death, date of birth, date of death, age of death, municipality of birth, and municipality of residence. We select all deaths of individuals up to one year born between 2010 and 2017. We then build a municipality-by-month of birth panel for the period above containing information on number of infant deaths (total and by cause of death). We disaggregated by specific causes - based on The International Classification of Health-Related Diseases and Problems, CID-10 - such as infectious diseases,

[3] According to Renova Foundation this identification is a result of collaborative work, with the help of specialists from different areas, environmental agencies and with the community itself. More information on: https://www.fundacaorenova.org/mapa-de-atuacao/

respiratory diseases, congenital anomaly and conditions originated in perinatal period. The goal was to investigate infant mortality by specific causes that could be related to population exposure to industrial pollution in the post-disaster period in affected municipalities. This panel was merged with births panel by municipality and month of birth. The consolidated dataset allows us to calculate infant mortality rates by municipality and month of birth.

In addition, the microdata from Hospitalization System (DataSus/SIH) gathers information about every hospitalization registered in Brazil by month of hospitalization and main cause - based also on CID-10. We then build a municipality-by-month of hospitalization panel over the 2010-2017 period containing information all of hospitalizations, in order to calculate total and by cause hospitalization rate. The main intention with the hospitalization rate is to verify how the burden of individuals received in the public health system of these municipalities varies, given a shock like the Mariana disaster. Some chapters of CID-10 were chosen to assess specific effects on diseases that may be associated with exposure to pollution in the post-disaster period.

To finish, for dependent variables related to birth outcomes and infant mortality we use as control some maternal characteristics (proportion of mothers below 18 years' old, proportion of mothers above 40 years' old and proportion of mothers with less than 8 years of schooling) and the percentage of the population covered by Family Health Program, provided by Basic Attention Department – Ministry of Health. On the other side, for dependent variables related to hospitalization we used as control only the percentage of the population covered by Family Health Program.

3.2. Economic Outcomes

The main dependent variable used to perform the analysis about economics shock is the municipal gross domestic product (GDP), provided by the Brazilian Institute of Geography and Statistics (IBGE). We constructed a year-panel from 2010 to 2017 with every municipality GDP and sectorial value added: services, industrial and agriculture/livestock.

Our secondary variable used to evaluate an economic shock - the aquaculture production value – is elaborated by the annual Municipal Livestock Survey, produced by IBGE. The use of aquaculture production value is a proxy for fishing economic activity once we do not have data of extractive fishing in Brazil. Unfortunately, aquaculture data is available only after 2013, limiting our panel to 2013-2017 period.

To complement our analysis, we used as dependent variable the agriculture production value as well, elaborated by the annual Municipal Agriculture Survey, in order to evaluate a potential impact on agriculture activity. This data is available from our whole panel - 2010 to 2017.

Table 1: Descriptive Statistics - Birth Outcomes, Infant Mortality and Controls

	Total	Impacted Pre-Treatment	Impacted Post-Treatment	Not Impacted Pre-Treatment	Not Impacted Post-Treatment
	mean (sd)	mean (sd)	mean (sd)	mean (sd)	mean (sd)
Proportion of low birth weight newborns	8.57	7.87	8.15	8.55	8.72
	(12.50)	(10.62)	(10.97)	(12.44)	(12.94)
Birth weight (grams)	3.153	3.197	3.190	3.150	3.153
	(243.25)	(207.32)	(215.59)	(243.09)	(248.82)
Proportion of preterm newborns	10.01	9.16	10.10	9.80	10.68
	(13.50)	(11.46)	(11.85)	(13.44)	(13.97)
Proportion of newborns with congenital anomaly	0.71	0.49	0.81	0.73	0.71
	(3.74)	(2.09)	(3.20)	(3.80)	(3.77)
Infant mortality rate	13.73	11.88	12.59	14.36	12.34
	(54.66)	(41.87)	(39.09)	(56.17)	(52.71)
Neonatal infant mortality rate	9.89	8.46	9.77	10.21	9.23
	(46.73)	(38.20)	(35.32)	(47.45)	(46.32)
Posneonatal infant mortality rate	3.84	3.42	2.82	4.15	3.11
	(28.63)	(17.56)	(16.16)	(30.38)	(25.28)
Infant mortality rate by respiratory diseases	0.44	0.24	0.51	0.51	0.25
	(10.03)	(2.77)	(7.10)	(11.32)	(6.42)
Infant mortality rate by infectious diseases	0.44	0.50	0.44	0.49	0.29
	(9.61)	(6.93)	(7.04)	(10.93)	(5.26)
Infant mortality rate by congenital diseases	2.95	2.50	2.76	2.97	2.97
	(25.84)	(14.51)	(15.25)	(25.67)	(27.86)
Infant mortality rate by perinatal diseases	8.33	7.32	8.40	8.64	7.63
	(42.90)	(36.72)	(34.59)	(43.61)	(42.14)
Proportion of mothers with less than 3 years of study	5.32	5.37	2.62	6.22	3.02
	(10.83)	(10.76)	(7.59)	(11.59)	(8.17)
Proportion of mothers between 4 and 7 years of study	24.59	25.55	18.92	26.66	19.15
	(20.31)	(17.74)	(16.28)	(20.71)	(18.61)
Proportion of mothers below 18 years old	8.69	9.04	7.91	9.00	7.86
	(12.37)	(11.62)	(11.14)	(12.52)	(12.08)
Proportion of mothers above 40 years old	1.69	1.51	1.95	1.64	1.82
	(5.87)	(5.35)	(6.74)	(5.79)	(6.11)
Proportion of black and brown mothers	55.90	56.69	68.51	54.36	59.30
	(32.40)	(31.63)	(27.72)	(32.64)	(31.64)
Percentage of the population served by Family Health Program	89.75	86.47	89.75	89.12	91.90
	(19.44)	(20.63)	(18.90)	(20.15)	(17.02)
N	89.376	3.150	1.170	62.020	23.036

Pre-Treatment period: January 2010 until October 2015. Post-Treatment period: November 2015 until December 2017.

Table 2: Descriptive Statistics - Hospitalization

	Total	Impacted Pre-Treatment	Impacted Post-Treatment	Not Impacted Pre-Treatment	Not Impacted Post-Treatment
	mean (sd)	mean (sd)	mean (sd)	mean (sd)	mean (sd)
Hospitalization Rate per 1000 hab.	5.02	5.22	4.51	5.09	4.54
	(1.91)	(1.78)	(2.07)	(1.91)	(1.96)
Hospitalization Rate by infectious diseases	0.33	0.37	0.28	0.33	0.28
	(0.42)	(0.38)	(0.31)	(0.42)	(0.35)
Hospitalization Rate by neoplasm diseases	0.31	0.35	0.42	0.30	0.31
	(0.30)	(0.26)	(0.26)	(0.30)	(0.31)
Hospitalization Rate by digestive diseases	0.49	0.51	0.40	0.50	0.45
	(0.35)	(0.34)	(0.30)	(0.36)	(0.34)
Hospitalization Rate by respiratory diseases	0.63	0.63	0.53	0.66	0.58
	(0.56)	(0.60)	(0.64)	(0.56)	(0.54)
Hospitalization Rate by skin diseases	0.08	0.07	0.08	0.08	0.08
	(0.14)	(0.09)	(0.10)	(0.14)	(0.14)
Population	25.800	46.620	50.448	24.389	25.619
	(96.657)	(82.311)	(91.399)	(96.060)	(100.213)
N	89.376	3.150	315	62.020	6.202

Pre-Treatment period: January 2010 until October 2015. Post-Treatment period: November 2015 until June 2017.

Table 3: Descriptive Statistics - Economic Outcomes

	Total	Impacted Pre-Treatment	Impacted Post-Treatment	Not Impacted Pre-Treatment	Not Impacted Post-Treatment
	mean (sd)	mean (sd)	mean (sd)	mean (sd)	mean (sd)
GDP (R$ 1.000)	786.683	1.700.463	1.455.007	758.827	697.075
	(4.049.434)	(3.741.628)	(3.253.929)	(4.175.157)	(3.717.303)
Farming VA	38.155	30.269	27.283	38.380	39.232
	(66.549)	(44.365)	(38.224)	(66.837)	(69.477)
Industrial VA	207.649	614.328	393.561	204.131	146.793
	(962.162)	(1.428.120)	(887.559)	(1.003.203)	(701.640)
Services VA	328.429	600.138	615.384	314.435	314.436
	(2.139.449)	(1.357.425)	(1.467.417)	(2.190.681)	(2.107.171)
N	7.448	270	90	5.316	1.772
Aquaculture Production Value (R$ 1.000)	971	1.761	990	829	1.080
	(3.538)	(5.029)	(3.145)	(2.595)	(4.449)
N	950	45	30	525	350
Agriculture Production Value (R$ 1.000)	42.154	33.013	28.202	41.852	45.191
	(92.177)	(72.734)	(61.017)	(89.340)	(103.736)
N	7.352	270	90	5.244	1.748

Pre-Treatment period: 2010 until 2015 (except for Aquaculture Production Value, which only has available data after 2013). Post-Treatment period: 2016 and 2017.

4. Identification Strategy

Assuming that the disaster caused an exogenous shock to social indicators at the local level, it is possible to apply a difference in differences model to compare the results of municipalities that were hit by the tailing mud with a control group - other municipalities in the states of Minas Gerais and Espírito Santo that have not been affected. We use here two different specifications, the first one to the health outcomes, based on monthly panel data and the second one to economic activity, based on annual panel data.

4.1. Birth Outcomes, Infant Mortality and Hospitalization Regressions

In all, the sample has 931 municipalities, 45 in the treatment group and 886 in the control group. The analysis is based on a monthly panel between 2010 and 2017[4]. The model is constructed as follows:

$$Y_{m,t} = \alpha + \beta T_{m,t} + \theta X_{m,t} + \delta_t + \varphi_{st} + \gamma_m + \varepsilon_{m,t}$$

Where $Y_{m,t}$ are the health indicators of municipalities m in period t (proportion of newborns with low weight, proportion of newborns with congenital anomaly, proportion of preterm newborns, infant mortality rate and hospitalization rate). $T_{m,t}$ is the dummy treatment, that is , whether the municipality was impacted or not, $X_{m,t}$ is a vector of municipal characteristics, δ_t is month-year fixed effects and γ_m municipalities fixed effects. The month-year fixed effect controls for changes over time that are common to all municipalities, whereas the municipality fixed effect controls for unobserved and time-invariant characteristics of each municipality. In addition, the φ_{st} is a state specific year-month fixed effect, used to capture differences between states nonlinear time trends. The parameter of interest is β, which measures the impact of the disaster on the indicators represented by variable Y.

4.2. GDP, Aquaculture and Agriculture Production Value Regressions

In all, the sample for GDP has 931 municipalities, 45 in the treatment group and 886 in the control group, as in the previous subsection. However, this quantity varies for each dependent variable, according to the information disposable. The sample of agriculture production value contains all treated municipalities but has 874 municipalities in the control group, while the

[4] In hospitalization panel data we dropped the last semester of 2017 due to data problems - notifications showed a strong decrease in these months.

sample of aquaculture value contains 15 municipalities in the treatment group and 175 municipalities in the control group. The analysis is based on an annual panel between 2010 and 2017, except for aquiculture production value due to restriction of available data – provided only after 2013. The model is constructed as follows:

$$Y_{m,t} = \alpha + \beta T_{m,t} + \delta_t + \varphi_{st} + \gamma_m + \varepsilon_{m,t}$$

Where $Y_{m,t}$ are the economic indicators of municipalities m in period t (GDP; industrial, services and farming value added; and aquaculture and agriculture production value). $T_{m,t}$ is the dummy treatment, that is, whether the municipality was impacted or not, δ_t is year fixed effects and γ_m municipalities fixed effects. The year fixed effect controls for changes over time that are common to all municipalities, whereas the municipality fixed effect controls for unobserved and time-invariant characteristics within the same municipality. In addition, the φ_{st} is a state specific year fixed effect, used to capture differences between states nonlinear time trends. The parameter of interest is β, which measures the impact of the disaster on the indicators represented by variable Y.

5. Results

5.1. Health Outcomes

We started our analysis looking to birth outcomes results, reported in table 4: proportion of newborns with low birth weight, birth weight in grams, proportion of preterm newborns and proportion of newborns with congenital anomaly. All regressions were weighted by total of births by municipalities. For each dependent variable, the columns report the beta coefficients of our base model. Signals of birth weight and proportion of newborns with congenital anomaly was as expected by the literature of in utero exposure. On the other side, it is worth noting that, contrary to what was expected, we find a negative sign in proportion of low birth weight and preterm births. However, we did not find any significant effect on any of these outcomes. So, it seems that being exposed to the disaster did not impacted birth outcomes on affected municipalities.

Table 4: Birth Outcomes

	(1) Low Birth Weight	(2) Birth Weight (grams)	(3) Preterm	(4) Congenital
Impacted*Post	-0.1438	-4.9476	-0.1049	0.0768
	(0.1706)	(7.2921)	(0.2298)	(0.0927)
Observations	87,377	87,377	87,377	87,377
R-squared	0.0049	0.0119	0.0640	0.0041
Number of municipalities	931	931	931	931
Year-Month FE	Yes	Yes	Yes	Yes
State Specific Year-Month FE	Yes	Yes	Yes	Yes
Municipalities FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors clustered at the municipality level. All regressions are based on municipality of residence of the mother and are weighted by total of births by municipalities. We considered as controls some maternal characteristics such as proportion of mothers with less than 8 years of study and proportion of black and brown mothers. We also considered as control the percentage of population covered by Brazilian Family Health Program.

Table 5 shows the results of the estimation to infant mortality rate and also to neonatal infant mortality rate i.e., infant mortality until 28 days of life. The intuition to separate a neonatal rate is to look to an indicator that is more sensible to this type of shock, once deaths is this period are strongly associated with the pregnancy period – mother channel. In this context, we did not find any significant effect on infant mortality rate, but we find a positive and significant effect on neonatal infant mortality rate – an increase of 9,3%, on average, with a significance of 5%.

Table 5: Infant Mortality Rate

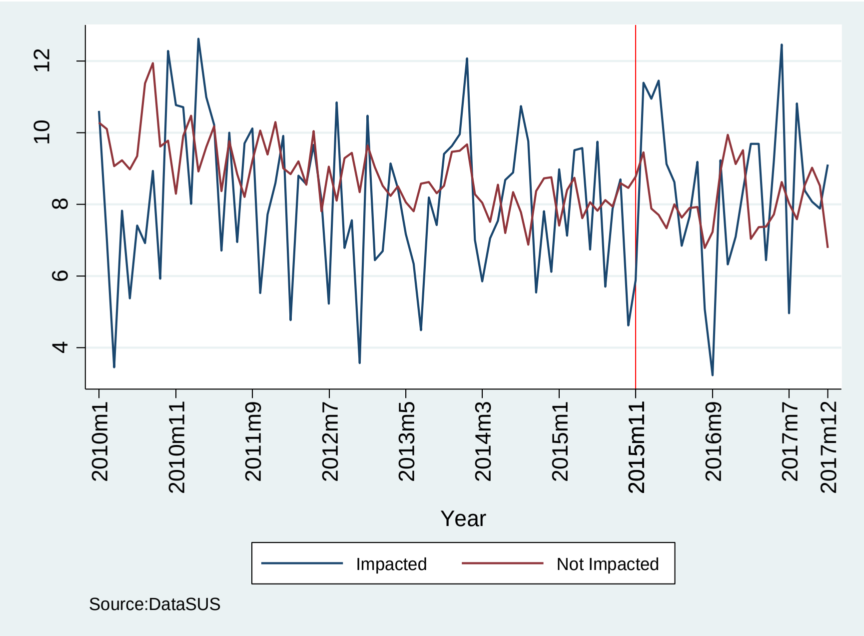
	(1) Total	(2) Neonatal (< 28 days)
Impacted*Post	0.6825	0.9210
	(0.5776)	(0.4258)**
Observations	87,377	87,377
R-squared	0.0036	0.0028
Number of municipalities	931	931
Year-Month FE	Yes	Yes
State Specific Year-Month FE	Yes	Yes
Municipalities FE	Yes	Yes
Controls	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

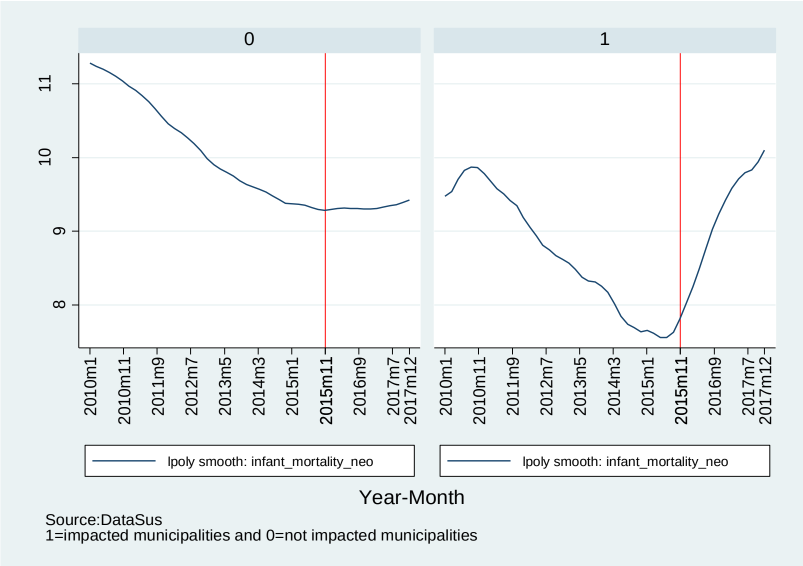
Robust standard errors clustered at the municipality level. All regressions are based on municipality of residence of the mother and are weighted by total of births by municipalities. We considered as controls some maternal characteristics such as proportion of mothers with less than 8 years of study and proportion of black and brown mothers. We also considered as control the percentage of population covered by Brazilian Family Health Program.

Figure 2: Neonatal Infant Mortality Rate



Source: DataSus data. Author's Elaboration.

Figure 3: Neonatal Infant Mortality Rate - Smoothed



Source: DataSus data. Author's Elaboration.

In order to complete our analysis about infant mortality rate, we broke it into some specific causes of death: mortality by infectious diseases, congenital problems, perinatal conditions and respiratory diseases. However, we did not find any significant impact on infant mortality by these causes.

Table 6: Infant Mortality Rate by specific causes

	(1) Infectious	(2) Congenital	(3) Perinatal	(4) Respiratory
Impacted*Post	-0.0622	-0.0072	0.6374	0.1406
	(0.0803)	(0.2470)	(0.4062)	(0.1239)
Observations	87,377	87,377	87,377	87,377
R-squared	0.0017	0.0023	0.0029	0.0020
Number of municipalities	931	931	931	931
Year-Month FE	Yes	Yes	Yes	Yes
State Specific Year-Month FE	Yes	Yes	Yes	Yes
Municipalities FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Robust standard errors clustered at the municipality level. All regressions are based on municipality of residence of the mother and are weighted by total of births by municipalities. We considered as controls some maternal characteristics such as proportion of mothers with less than 8 years of study and proportion of black and brown mothers. We also considered as control the percentage of population covered by Brazilian

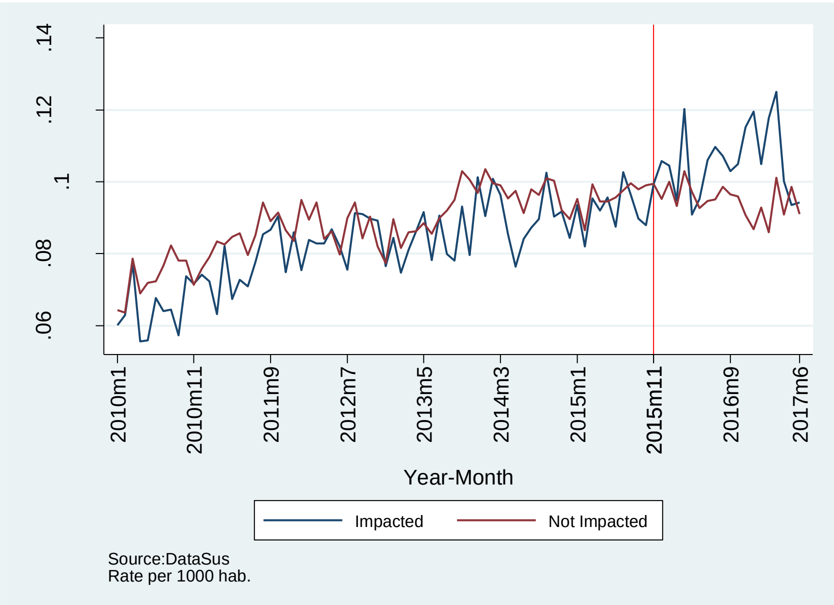
To finish our health outcomes, table 7 presents the results for hospitalization rate per 1000 habitants and by specific diseases. In this case our analysis goes until June of 2017 due to data availability. Taking this into account, we find a positive impact of 12%, on average, on hospitalization due to skin diseases, significant at 10%. Figure 4 seems to corroborate our result, once the rate of impacted group goes above the rate of control group after November of 2015. This could be explained by the contact with the dry mud of mining tailings, as notified by some people, especially in municipalities closest to the dam, in some qualitative analysis.

Table 7: Hospitalization Rate per 1000 hab. and by specific diseases

	(1) Total	(2) Infectious	(3) Neoplasm	(4) Digestive	(5) Respiratory	(6) Skin
Impacted	0.0869	-0.0016	0.0097	-0.0215	0.0123	0.0096
	(0.1570)	(0.0207)	(0.0146)	(0.0272)	(0.0208)	(0.0053)*
Observations	83,790	83,790	83,790	83,790	83,790	83,760
R-squared	0.1100	0.0339	0.0906	0.0314	0.1567	0.0218
Number of municipalities	931	931	931	931	931	931
Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
State Specific Year-Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Municipalities FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors clustered at the municipality level. All regressions are based on municipality of residence and are weighted by municipalities' average population. We considered as control the percentage of population covered by Brazilian Family Health Program.

Figure 4: Hospitalization Rate by Skin Diseases



Source: DataSus data. Author's Elaboration.

5.2. Economic Outcomes

From the economic point of view, Table 8 presents the results for GDP and each one of its components. It is possible to see that municipalities affected by the disaster suffered a drop of 5,4%, on average, in their GDP, at 10% of significance. Even more significant and larger was the negative effect on industrial sector. Column 3 shows that this sector has undergone a fall of 13,8%, on average, on its value added. Figures 5 and 6 illustrate GDP and industrial value-added path since 2010, giving strength to our results. Both seems to have similar trends for impacted and non-impacted groups in the period before the tragedy and the first group seems to have a negative slope in 2016.

The disaster take place in November 2015, so it is unlikely that this year was economically impacted, but it could be happened somehow. So, to improve our analysis, we did a second specification, excluding the year of 2015 of our pre-disaster period once this could be inducing some confusion on our results. This second specification is presented in columns 5 to 8 and show that both negative impact holds on. Actually, when 2015 is dropped out, the coefficients are even higher: decrease of 5,7% on average on GDP and decrease of 13,9% on average on industrial activity.

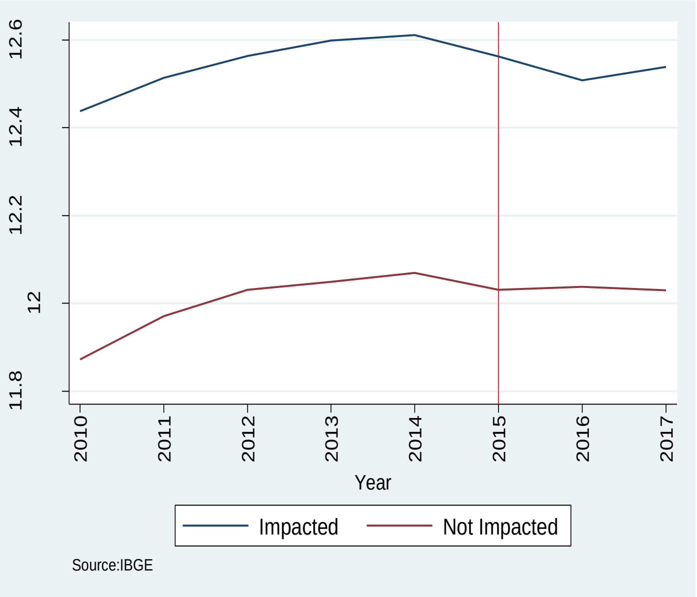
In general, the industry performance might have been impacted by the mineral extractive sector, once there was a partial standstill of mining activities in some localities owing to judicial precautionary measures or even production interruptions by decommissioning dams in the sector. Besides that, we could expect an indirect chain effect on other industrial sectors that are connected with mining, such as product suppliers or metal production.

Table 8: GDP, Agriculture, Industrial and Services Value Added

Including 2015	(1) GDP	(2) Agriculture and livestock VA	(3) Industrial VA	(4) Services VA
Impacted*Post	-0.0545	-0.0636	-0.1384	-0.0227
	(0.0281)*	(0.0425)	(0.0560)**	(0.0221)
Observations	7,448	7,448	7,448	7,448
R-squared	0.1505	0.0862	0.0396	0.3871
Number of municipalities	931	931	931	931
Year FE	Yes	Yes	Yes	Yes
Municipalities FE	Yes	Yes	Yes	Yes
Excluding 2015	**(5) GDP**	**(6) Agriculture and livestock VA**	**(7) Industrial VA**	**(8) Services VA**
Impacted*Post	-0.0571	-0.0585	-0.1399	-0.0236
	(0.0312)*	(0.0445)	(0.0625)**	(0.0244)
Observations	6,517	6,517	6,517	6,517
R-squared	0.1620	0.0921	0.0428	0.3927
Number of municipalities	931	931	931	931
Year FE	Yes	Yes	Yes	Yes
Municipalities FE	Yes	Yes	Yes	Yes

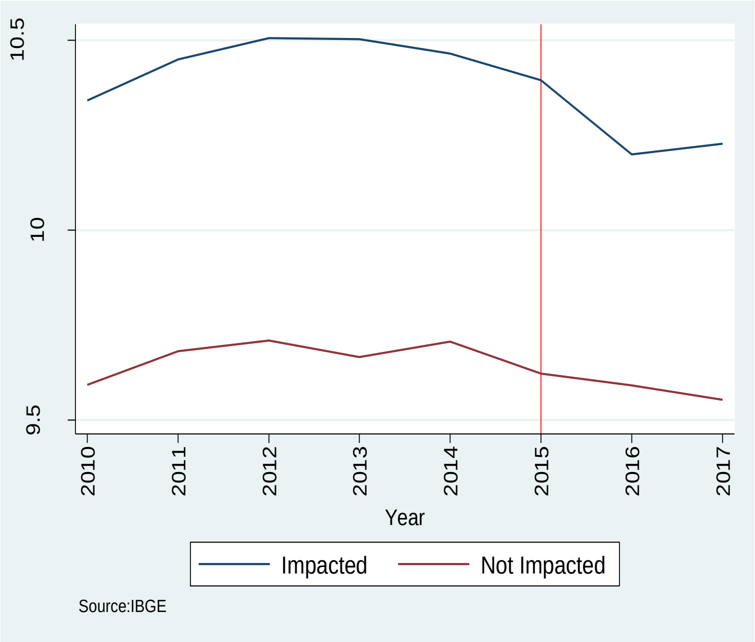
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Dependent variables are deflated at prices of 2017 and are ln transformation. Columns (5)-(8) exclude 2015 year.

Figure 5: Municipal GDP - 2010 to 2017



Source: IBGE data. Author's Elaboration

Figure 6: Industrial VA - 2010 to 2017



Source: IBGE data. Author's Elaboration

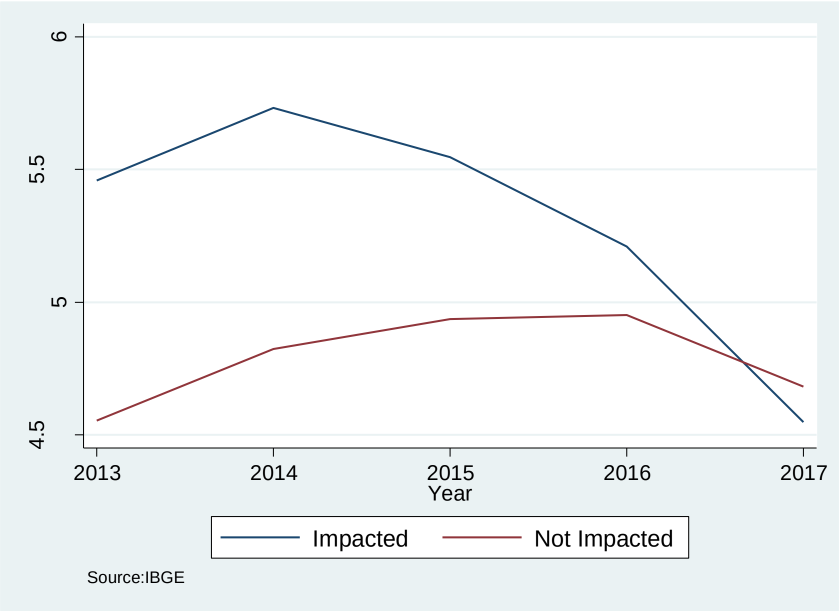
Table 9 presents the results for aquaculture production value. We use this variable as a proxy for fishing economic activity once we do not have public data of extractive fishing in Brazil. It is important to notice that the number of municipalities fall drastically because we only considered municipalities with complete panel data. To investigate whether 2015 is distorting the results or not we also made two specifications, the second one excludes 2015 year. Both coefficients are negative at the 5% level. When considering 2015, aquaculture production value seems to be reduced in 5,9%, on average, against a decrease of 6,4% when excluding 2015.

Table 9: Log of Aquaculture Production Value

	(1) Ln Aquaculture Production Value	(2) Ln Aquaculture Production Value
Impacted*Post	-0.5954	-0.6488
	(0.2695)**	(0.2827)**
Observations	949	759
R-squared	0.0845	0.0894
Number of municipalities	190	190
Year FE	Yes	Yes
State Specific Year FE	Yes	Yes
Municipalities FE	Yes	Yes
Drop 2015	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors clustered at the municipality level.

Figure 7: Log of Aquaculture Production Value - 2013 to 2017



Source: IBGE data. Author's Elaboration

To finish, we investigate whether the agriculture of the impacted municipalities might have been affected by the disaster. This could be happened, especially in the municipalities closest to the dam, where besides the water pollution, the soil pollution was intensive. Nevertheless, differently of what we thought at first place, we did not find any significant impact on agriculture production value (Table 10), corroborating the lack of effect on this sector presented in table 3.

Table 10: Log of Agriculture Production Value

	(1) Ln Agriculture Production Value	(2) Ln Agriculture Production Value
Impacted*Post	-0.1027	-0.1030
	(0.0690)	(0.0698)
Observations	7,352	6,433
R-squared	0.2230	0.2360
Number of municipalities	919	919
Year FE	Yes	Yes
State Specific Year FE	Yes	Yes
Municipalities FE	Yes	Yes
Drop 2015	No	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
Robust standard errors clustered at the municipality level.

6. Robustness Checks

Treatment and control groups do not necessarily need to have the same conditions before intervention. However, for the method to provide a valid estimate of the counterfactual, we need to assume that there are no time-varying differences between treatment and comparison groups. That is, results must show equal trends in the absence of treatment. Although we cannot prove it, the validity of the underlying hypothesis of similar trends can be tested. A first check is to compare changes in affected and control group outcomes before the disaster. Had the results evolved together in the pre-disaster period, we gain confidence that the results would have continued to advance together after the intervention (Gertler et al, 2018).

A second way to test the validity of the results is to run a placebo test. The test is based on making an estimation using a year of fake treatment, for example, a year in which the shock did not occur (Gertler et al, 2018). To run this test, we used many fake years, producing what is known as an event study. In the monthly panel data, we took the nearest pre-treatment month out of the regression while in the annual panel data the baseline was the year of 2015. In this case, we would like to see any effect on periods before the disaster.

6.1. Economic Outcomes

Regarding our GDP result, the first check seems to be consistent once we do not find significant difference in trends in the pre-treatment period between treatment and control groups (Table 11). Moreover, we conducted an event study where we regress the GDP on different time dummies interacted with our treatment variables, being our baseline the year of 2015 (zero in figure 8). As expected, no significant effect was found considering the treatment in a five years lag, being the only significant effect a decline in 2016. Interestingly, in 2017 this effect seems to not persist. (Figure 8).

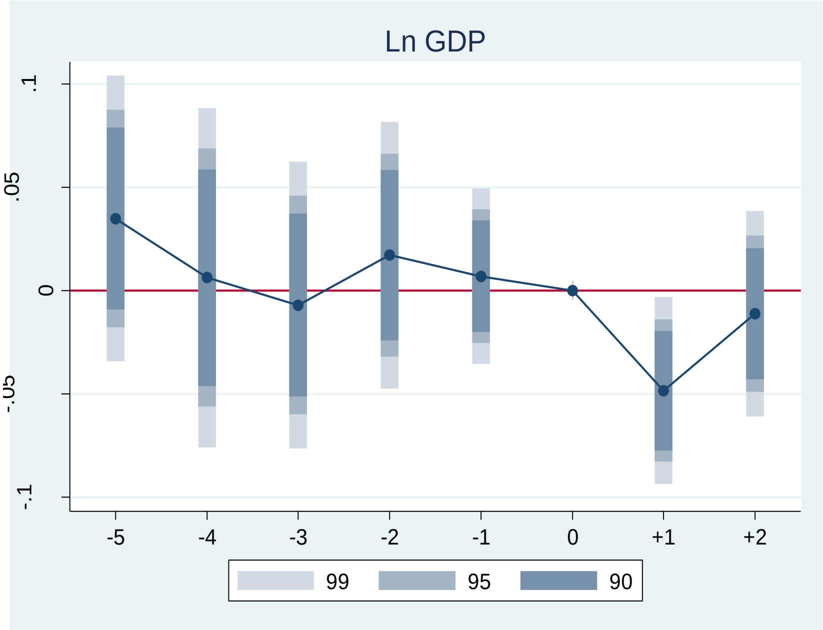
The same exercises were done for industrial value added and aquaculture production value - the dependent variables that we want to verify the strength of our results. Doing the same trend check for both variables, we did not find significant differences in pre-treatment trend between affected and non-affected groups (Tables 12 and 13), neither effects in pre-treatment years in the event study (Figures 9 and 10). Figure 9 presents a negative effect in the first year after the disaster that, such as the GDP effect, fade out in the second post-disaster year. Figure 10 for its turn, presents a negative effect in the year$_{t+2}$. In both, as expected, we do not find any effects in the placebo years, i.e. before 2015.

Table 11: GDP Trend Check

	(1)	(2)
Trend <= 2015	GDP	GDP
Impacted*Trend	-0.0048	-0.0135
	(0.0056)	(0.0195)
Impacted*(Trend)^2		0.0012
		(0.0030)
Observations	5,586	5,586
R-squared	0.2106	0.2106
Number of municipalities	931	931
Year FE	Yes	Yes
Municipalities FE	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
GDP deflated at prices of 2017

Figure 8: Event Study - GDP



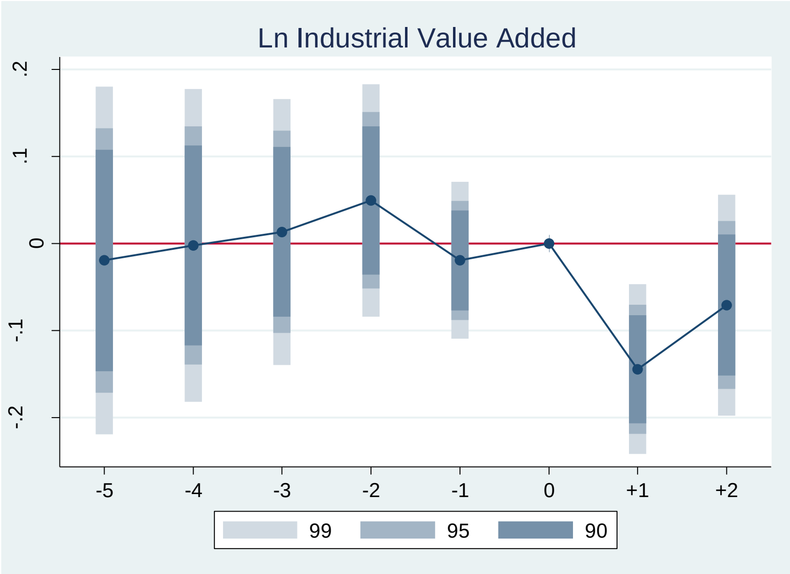
Source: IBGE data. Author's Elaboration.

Table 12: Industrial Value Added Trend Check

Trend <= 2015	(1) Industrial VA	(2) Industrial VA
Impacted*Trend	0.0037	0.0602
	(0.0160)	(0.0416)
Impacted*(Trend)^2		-0.0081
		(0.0055)
Observations	5,586	5,586
R-squared	0.0290	0.0293
Number of municipalities	931	931
Year FE	Yes	Yes
Municipalities FE	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
GDP deflated at prices of 2017

Figure 9: Event Study - Industrial Value Added



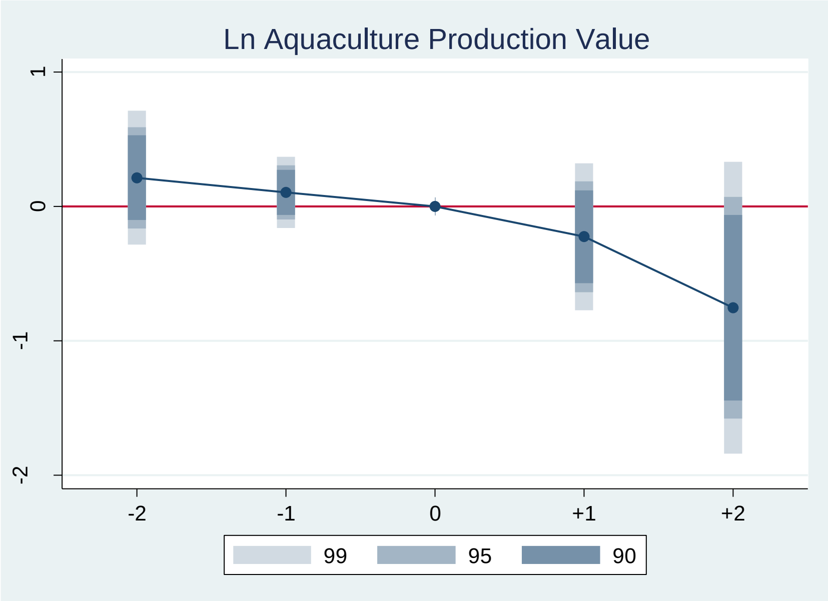
Source: IBGE data. Author's Elaboration.

Table 13: Aquaculture Production Value Trend Check

	(1) Ln Aquaculture Production Value	(2) Ln Aquaculture Production Value
Impacted*Trend	0.0241	0.3978
	(0.0616)	(0.3256)
Impacted*(Trend)^2		-0.0630
		(0.0480)
Observations	570	570
R-squared	0.0614	0.0633
Number of municipalities	190	190
Year FE	Yes	Yes
Municipalities FE	Yes	Yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 10: Event Study - Aquaculture Production Value



Source: IBGE data. Author's Elaboration.

6.2. Health Outcomes

In this section we do the same exercises as the previous one. First, we conduct a trend verification for the pre-treatment period, to compare trends for impacted and non-impacted groups. Furthermore, we present the event study analysis, but now with previous 12 months and posterior 12 months as placebos since we are leading with a monthly panel data.

Table 14 shows the trend verification for hospitalization rate by skin diseases. We can see that there is no significant difference between both groups, neither using a linear trend nor quadratic trend. That is a good thing, because we see that groups had similar trends before the disaster. When conducting the second robustness check, however, we can see that the event study does not present a clear impact. Hospitalization by skin diseases appears to have a slightly increase, but not very significant (Figure 11).

Aiming to have a better view of it, we did a third exercise, where we accumulate this data in 12 months[5]. Figure 12 shows that, when accumulating the data, the effect shows up in the two post-disaster periods.

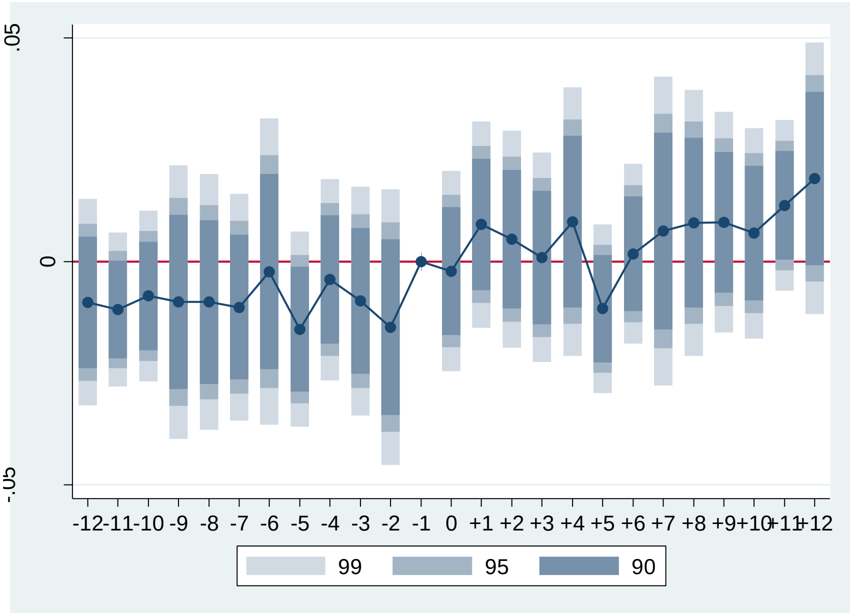
[5] Example: t-1 aggregates the following months: November of 2014 until October of 2015. t +1 aggregates the following months: November of 2015 until October of 2016.

Table 14: Skin Hospitalization Rate Trend Check

	(1)	(2)
Trend <= 2015.10	Skin Hosp.	Skin Hosp.
Impacted*Trend	-0.0002	0.0000
	(0.0001)	(0.0004)
Impacted*(Trend)^2		-0.0000
		(0.0000)
Observations	65,150	65,150
R-squared	0.0216	0.0216
Number of municipalities	931	931
Year-Month FE	Yes	Yes
State Specific Year-Month FE	Yes	Yes
Municipalities FE	Yes	Yes

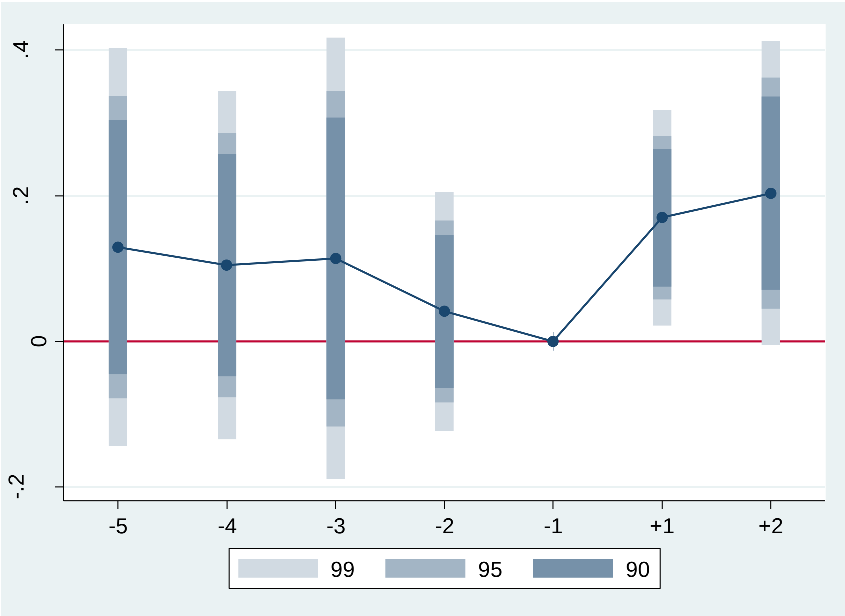
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 11: Event Study - Hospitalization by Skin Diseases



Source: DataSus data. Author's Elaboration.

Figure 12 - Event Study - Hospitalization by Skin Diseases - Accumulated 12 months



Source: DataSus data. Author's Elaboration.

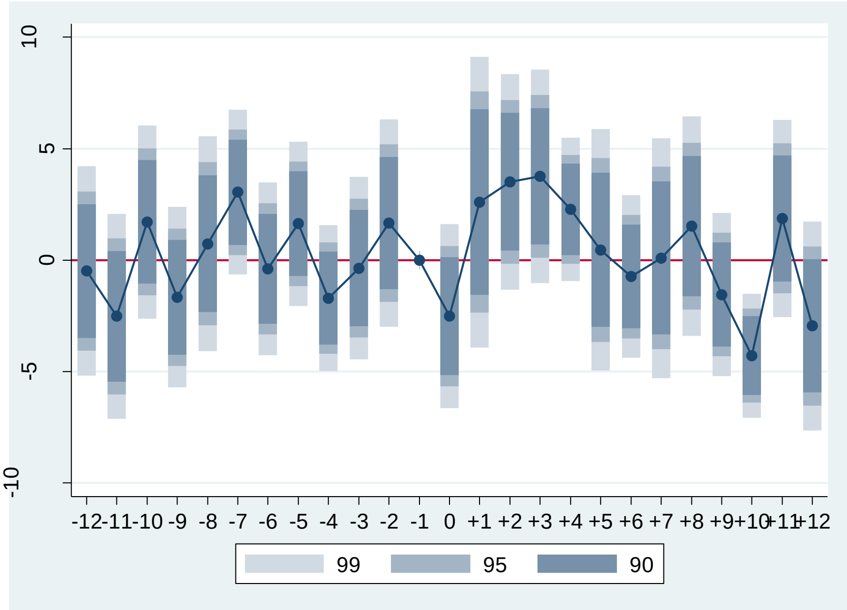
To finish our analysis, we conduct the same robustness checks for neonatal infant mortality rate. Table 15 presents the trend verification for this outcome. It is possible to see that there is no significant difference between treatment and control groups in pre-disaster period, neither using a linear trend nor a quadratic trend. For the second robustness check the event study shows a little positive effect in the immediate months after the tragedy, that fades away after few months (Figure 13). However, in this case, the event study with 12 months accumulated does not show any effect (Figure 14).

Table 15: Neonatal Infant Mortality Rate Trend Check

	(1)	(2)
Trend <= 2015.10	IMR: Neonatal	IMR: Neonatal
Impacted*Trend	0.0144	0.0553
	(0.0137)	(0.0452)
Impacted*(Trend)^2		-0.0006
		(0.0005)
Observations	63,771	63,771
R-squared	0.0025	0.0025
Number of municipalities	931	931
Year-Month FE	Yes	Yes
State Specific Year-Month FE	Yes	Yes
Municipalities FE	Yes	Yes

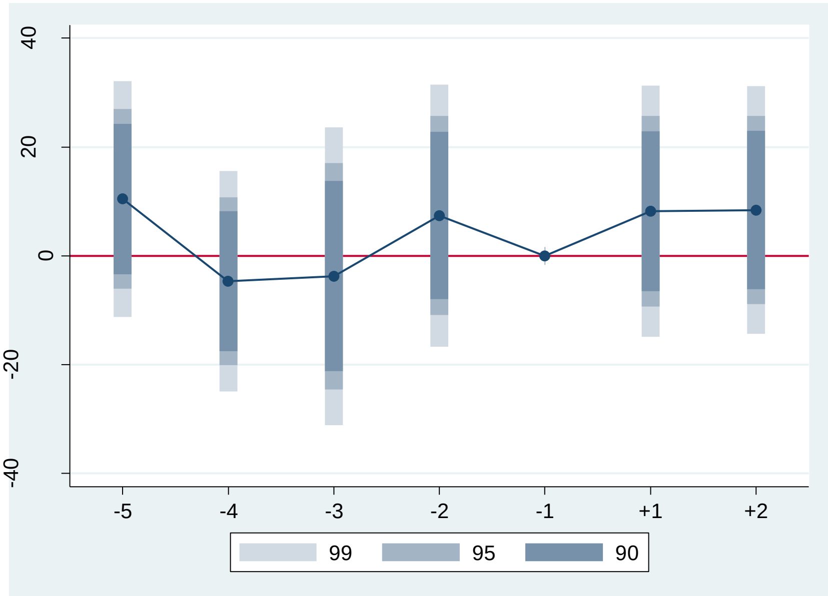
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 13: Event Study - Neonatal Infant Mortality Rate



Source: DataSus data. Author's Elaboration.

Figure 14: Event Study - Neonatal Infant Mortality Rate - Accumulated 12 months



Source: DataSus data. Author's Elaboration.

7. Final remarks

This work empirically investigates the impact of the Mariana dam failure that happed in the state of Minas Gerais, in November of 2015, on surrounding municipalities. The tragedy is considered one of the biggest Brazilian environmental disaster because the dam breakage spread millions of cubic meters of mining tailing along the Rio Doce River course. Not only it has caused a huge shock in terms of pollution, but also it generated a shock the economic activity in this area. The pollution shock, as argued, could bring negative consequences to the health of population is this municipalities, besides compromising the rivers dependent economic activity. In addition, the partial standstill of mining production could have caused a negative economic impact in this municipalities.

In that context, we used a difference-in-differences approach to capture potential causal relation in being affected by the disaster on some health and economic outcomes. In order to do it we used data from Brazilian Health Informatics Department (DataSus) and from Brazilian Institute of Geography and Statistics (IBGE). To do the health analysis we used a monthly panel data to have a more detailed scenario. On the other side, in the economic analysis we used a year panel data owing the lack of monthly variables in a municipality level.

In the health outcomes, we find a positive significant impact on neonatal infant mortality (+9,3%) and hospitalizations due to skin diseases (+12%). In the economic outcomes, we find a negative impact on municipal GDP (-5,4%), especially in industrial sector (-13,8%), and also on aquaculture production value (-5,9%). To verify our results, we conduct some robustness checks, presented in section 6. Both the economic and health estimates are robust when applying the pre-treatment trend check and the event study.

In general, we contribute to the literature on how environmental disasters may impact health and local economy estimating the impact of a huge mining dam breakage in a development context. More specifically, the Mariana tragedy besides being an environmental disaster was also a technological disaster, turning essential the production of quantitative analysis for evaluating welfare impacts of mineral activity in developing countries and think about the design of environmental regulation policies.

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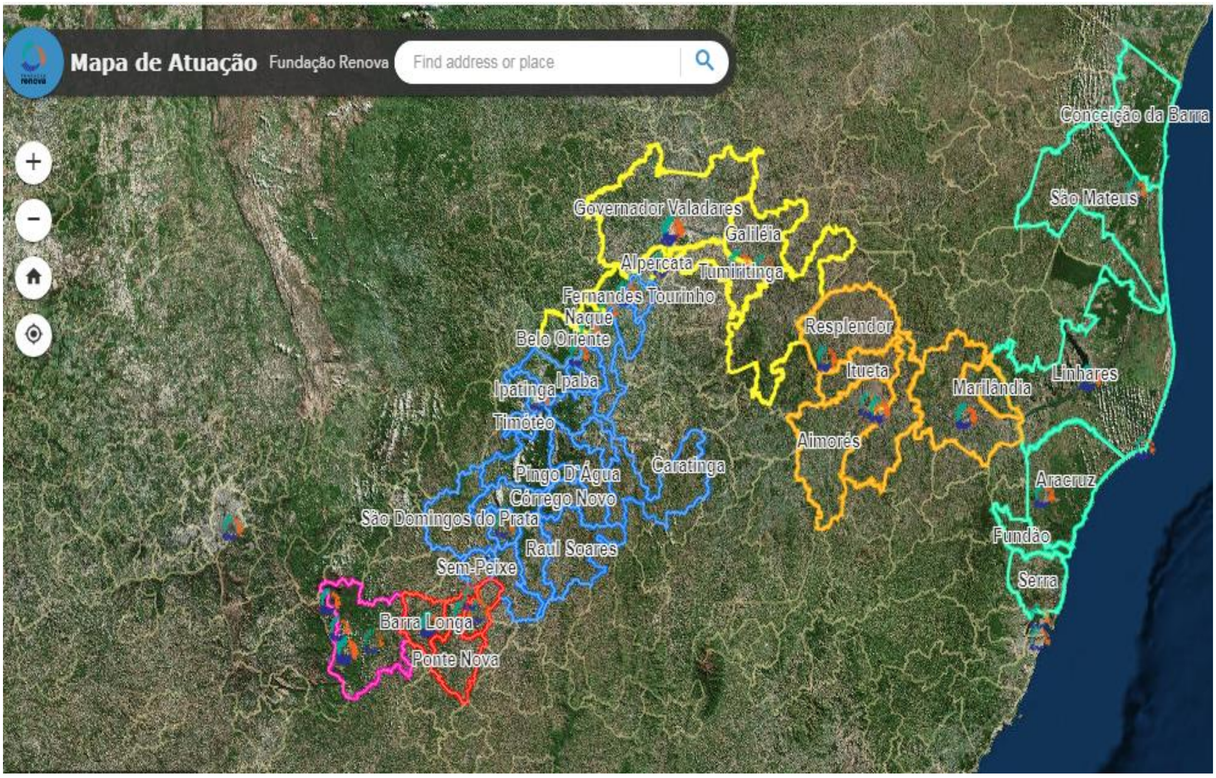
Appendix

Figure 15: Affected Municipalities



Source: Renova Foundation

Table 16: Affected Municipalities

IBGE Code	Municipalities
312770	Governador Valadares
312730	Galiléia
311840	Conselheiro Pena
316950	Tumiritinga
310180	Alpercata
314995	Periquito
312580	Fernandes Tourinho
315430	Resplendor
314435	Naque
316770	Sobrália
310630	Belo Oriente
312930	Iapu
313410	Itueta
310925	Bugre
315895	Santana do Paraíso
313115	Ipaba
310110	Aimorés
311340	Caratinga
316870	Timóteo
310780	Bom Jesus do Galho
314030	Marliéria
315053	Pingo D`Água
312180	Dionísio

IBGE Code	Municipalities
312000	Córrego Novo
316340	São José do Goiabal
316400	São Pedro dos Ferros
315490	Rio Casca
316556	Sem-Peixe
314000	Mariana
315740	Santa Cruz do Escalvado
315500	Rio Doce
310570	Barra Longa
313130	Ipatinga
316100	São Domingos do Prata
320060	Aracruz
320320	Linhares
320150	Colatina
320080	Baixo Guandu
320335	Marilândia
315400	Raul Soares
320160	Conceição da Barra
320220	Fundão
320490	São Mateus
320500	Serra
315210	Ponte Nova

Source: Renova Foundation