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EXTERNALITIES IN TERRITORIES WITH THE PRESENCE OF MINING MHIS IN THE STATE OF MINAS GERAIS

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ABSTRACT

This paper aimed to investigate socioeconomic externalities caused by mining companies in the territories where the companies are established, considering the state of Minas Gerais, intensive in this kind of activity. For that, statistical techniques such as Factor Analysis and Propensity Score Matching (PSM) models were used to estimate the effect of the presence of mining companies. The results showed that territories with the presence of these MHIs have a higher GDP per capita than those that do not. Furthermore, the establishment of these companies tends to reduce local vulnerabilities. These results could be associated, because income increases could generate a reduction in vulnerabilities.

Keywords: Externalities; Mining Companies; Vulnerability; Income

RESUMO

Este trabalho pretendeu investigar externalidades socioeconômicas provocadas por mineradoras aos territórios onde estão estabelecidas, considerando o estado de Minas Gerais, intensivo neste tipo de atividade. Para tanto, foram utilizadas técnicas estatísticas como a Análise Fatorial e *Propensity Score Matching* (PSM) para estimação do efeito da presença das mineradoras sobre alguns marcadores socioeconômicos. Os resultados demonstraram que territórios com a presença dessas MHIs possuem o PIB per capita mais alto do que aqueles que não as possuem. Além disso, o estabelecimento dessas empresas tende a reduzir as vulnerabilidades locais. Esses resultados podem estar associados, dado que aumentos de renda podem gerar redução nas vulnerabilidades.

Palavras-chave: Externalidades; Mineradoras; Vulnerabilidade; Renda

Código JEL: C01, C21, D62

INTRODUCTION

Impacts from the activities of Major Hazard Installations (MHIs), such as mining companies, raise questions about their socioeconomic cost–benefit. Despite environmental degradation and the risks associated with tailings dam ruptures, the mining industry tends to play a central role in the economies of states and municipalities. Thus, the importance of mining as a raw material-producing activity essential to the well-being of the population and economic activity is challenged with the potential environmental and social impacts of the activity (Mancini; Sala, 2018).

Regarding externalities, in general, the concept consists of a "spillover" effect, that is, the impacts that occur whenever an actor fails to take the cost or secondary benefit into account about his action on a third party, which can be positive or negative, according to the effect caused (Boudreaux; Meiners, 2019).

Externalities are ubiquitous in academic literature, and despite the large number of analyses on the subject, most of them do not involve the economic evaluation of industrial externalities (Boudreaux; Meiners, 2019; Shein; Ye; Zhu, 2018). Furthermore, the literature is still incipient with respect to the externalities arising from mining MHIs. In addition, there is no consensus on the effects of mining on the socioeconomic development of a territory (Denes, 2018).

Mining industries provide most of the resources necessary for the infrastructure and instruments used daily, including large amounts of energy and fertilizers essential for supplying agriculture and supporting the production of most food. Nonetheless, according to Carvalho (2017), this human activity can be harmful to the environment and is linked to major social impacts and inequalities. However, the future of society is highly dependent on mining (Carvalho, 2017).

Due to the recent events that triggered environmental impacts in Brazil, the Brazilian literature has been strongly dedicated to the measurement and description of these aspects of the sector, from the economic, social or environmental perspectives (for example, in Carvalho, 2018; Da Silva; Ferreira; Scotti, 2015; Guedes; Schneider, 2018; Lopes, 2016).

According to Silva (1995), the first mining reference is defined in the state of Minas Gerais. The mineral extractive industry is one of the pillars of the state's economy, despite presenting controversial aspects. On the one hand, there is significant income generation; on the other hand, there is a tendency to depend on mineral activity (Nahas, 2014) in addition to the risks associated with the presence of these companies.

Given this context, the research question that this study aims to answer is as follows: what are the socioeconomic externalities caused by mining companies in the territories where they are established, considering the state of Minas Gerais? Given the relevance of the activity as a driver of the national economy, it is essential to analyze its externalities as an instrument for fostering local development so that the proposals for regulation and government policies become more effective, by either reducing its potential negative impacts or by promoting its economic stimulus.

Thus, MHIs, especially mining companies, produce contradictory externalities to the territory in which they are established and that these factors should be considered and weighed together for the decision to establish these organizations in a specific location. In Minas Gerais, in particular, the risk posed by the presence of these companies contrasts with the high economic dependency on their activities. This study will contribute to measuring the dimensions of this impact, especially in relation to vulnerabilities and local income.

In this sense, the main objective is to investigate the externalities generated on both income and vulnerabilities in territories with the presence of mining MHIs in the state of Minas Gerais. For this purpose, it is proposed to identify the variables that define the presence of a mining company in the territory and to analyze the externalities in the locations where these MHIs are established in comparison with similar territories that do not have such companies.

THEORETICAL FRAMEWORKS

Externalities

The concept of externalities was introduced in economic theory by Marshall (1920), who developed his theory around external costs. He primarily viewed these in terms of industrial policy, considering that external economies could be obtained by the concentration of companies engaged in similar activities, for example, through productive specialization and economies of scale (Boudreaux; Meiners, 2019; Marshal, 1920; Shein; Ye; Zhu, 2018).

Humphrey and Schmitz (1996) state that externality is the "side effect" generated in an activity, which can be positive when desired and negative when undesired. Corroborating this concept, Boudreaux and Meiners (2019) state that a common definition for externality is that it consists of a "spillover" effect that arises whenever an actor fails to take into account the cost or benefit that some part of his action has with regard to a third party. These authors admit that positive externalities are the unintended benefits of being charged for providing, and negative externalities are the unintended costs of being charged for not providing. This concept has the following main characteristics: externalities are priceless goods; they have a high social cost for those who receive them and can be characterized as public goods since they affect the people in society without distinction (Marta, 1999).

According to Stiglitz (2000), an externality is a market failure, in which the action of an individual or firm entails a consequence that affects other individuals and is not considered in the costs and/or revenues of the cause of the externality. The externalities that cause losses are called negative externalities. Regarding such externalities, the author admits that when the only firm takes its private cost into account, there is an excess in production. In the presence of these effects, the company should internalize the social cost, reduce production and take responsibility for the negative externalities generated (Stiglitz, 2000).

The conceptions of Demsetz (1967) and Milgrom and Roberts (1992) assume that externalities can be seen as market failures. These authors associate the concept of externality with property rights. According to Milgrom and Roberts (1992), externalities are positive or negative effects that the actions of an economic agent have on the well-being of others, highlighting that these effects are not regulated by the price system. This concept includes external costs and benefits, in addition to pecuniary and nonpecuniary externalities (Demsetz, 1967).

Demsetz (1967) focuses on the issue of the economic efficiency of property rights and considers that community property rights are more subject to externalities, as when many have the right to use a resource, they tend to generate excessive use. Similarly, when many have the duty to provide a resource, it will be offered below the needs. Thus, the solution would be a definition of attribution of property rights so that the "internalization" of the externalities around the agent that has the right to use them occurs, which stimulates a more efficient manipulation of the resource.

Lemos, Santos and Crocco (2003) classify externalities according to a territorial dimension – national (institutional and structural), regional (Perrouxian) or local. According to this classification, this study focuses on local externalities, which can be of four types: Marshallian, Schumpeterian, transactional and Jacobian. The Marshallian externalities would be linked to the productive dimension; the Schumpterian, to the innovative; the transactional ones, to the frequent and recurrent exchanges of information and knowledge between local actors; and the Jacobians, to the urban dimension (Pugas; Calegary; Antonialli, 2013).

The perspective used in this study, which is the Marshallian externalities, originate from i) productive chains in the form of intersectoral exchanges; ii) the constitution of a local labor market with specific qualifications accumulated by experience; and iii) technological gains via knowledge spillovers (Lemos; Santos; Crocco, 2003).

With respect to Marshallian theory, "agglomeration externalities" have recently been discussed extensively. These externalities arise as constituted groups benefit from the action in a cluster. They refer to impacts resulting from contact between companies, producing knowledge spillovers. The concentration of skilled labor, specialized services, and infrastructure, among other elements, can also induce the efficiency of productive activities. The larger the network involved in this exchange, the greater the joint benefits, since the joint action tends to produce greater benefits than the individual action – referred to in the literature as synergy production (Boudreaux; Meiners, 2019; Weston; Siu; Johnson, 2001; Wheaton; Lewis, 2002).

For Shen, Ye and Zhu (2018), the most common definitions adopted on externalities concern the position of the subject: one is based on the subject that produces externalities, and the other is based on the subject that receives the externalities. The first part of the assumption is that an economic subject exerts an external influence on another economic subject, and this external influence cannot be bought or sold at the market price. The second assumes that externality is used to indicate certain benefits or costs of an action that go beyond those considered by the decision-maker (i.e., certain benefits or costs are imposed on external subjects).

Huang, Hong and Ma (2020) summarize that an externality can be divided into four categories based on the criteria of factory, company, industry and city: external economies internal to firms; Marshall-Arrow-Romer (MAR) externalities, which assume that an externality is linked to learning and this is the basis of economic growth, which relates to specialization; externalities of Jacobs, or dynamic urbanization economy, which assumes the existence of different industries in the same city, that is, the dynamic externalities are derived from diversification; and the externality of the urban network, which occurs between different cities and industries, being provided by the interconnection. If the externalities are MAR, the cities involved in this industry tend to specialize only in an export activity or a closely connected set of activities. Specialization allows the full exploitation of economies of scale. However, if an industry is subject to the externalities of Jacobs, it needs to be diversified so that it can thrive (Henderson, 1997).

In addition, economists have long distinguished "technological" from "pecuniary" externalities. The first is more intangible; it refers to production costs, obtained through transactions outside the market. Within a company, they can be exemplified as savings in labor, materials or equipment requirements per unit of production resulting from a better organization or production methods, acquired through factors related to knowledge flows. The pecuniary externalities are more tangible and may occur through market transactions or interorganizational ties. These have advantages in the purchase, such as quantity discounts on the purchase of raw materials. Although distinctions are made between technical and pecuniary economies, the form does not matter to the company or to the decision-maker, since both results represent benefits or losses (Boudreaux; Meiners, 2019; Johansson, 2005).

According to Cunha et al. (2019), the mineral sector generates positive and negative externalities. The positive results in the economic field are measured by the production and commercialization of mineral goods, the supply of jobs and the generation of revenue for the public coffers through taxes and royalties. In addition, the extraction and processing of ore produce effects on social development, such as the Human Development Index (HDI). However, the activity also generates negative externalities to the regions and their surroundings, which absorb the socioenvironmental costs of mining, revealing the need to improve the instruments of public management and safety in the operations of companies in the sector (Cunha et al., 2019).

Thus, what can be concluded about the study of externalities is that, in general, externalities, regardless of their size, are random effects of a given activity, which can have a positive or negative impact on society. These results can be enhanced based on the characteristics of the organizations of the local productive arrangements involved.

Therefore, Boxes 1 and 2 summarize the main concepts referenced on the subject and the most used classifications, respectively.

Box 1: Externalities: relevant concepts

Concept	Author
They are positive or negative effects that the actions of an economic agent have on the well-being of third parties, highlighting that these effects are not regulated by the price system.	Milgrom and Roberts (1992)
It is the side effect generated in an activity, which can be positive when desired and negative when undesired.	Humphrey and Schmitz (1996)
It is a market failure, in which the action of an individual or firm entails a consequence that affects other individuals and is not considered in the costs and/or revenues of the cause of the externality.	Stiglitz (2000)
It is the "spillover" effect that arises whenever an actor fails to consider the cost or benefit that some part of his action has on a third party, which can be positive or negative, according to the effect caused.	Boudreaux and Meiners (2019)

Source: own elaboration.

Box 2: Main classifications of the concept of externalities

Classification	Concept
Negative externalities	Occurs when the side effect of an activity is undesirable (Humprey; Schmitz, 1996), they are unviable benefits of charging to provide (Boudreaux; Meiners, 2019).
Positive externalities	Occurs when the side effect of an activity is desired (Humprey; Schmitz, 1996), they are unviable costs to charge for not providing (Boudreaux; Meiners, 2019).
Local externalities	i) Marshallian externalities, linked to the productive dimension (focus of this study); ii) Schumpterian externalities, related to the innovative dimension; iii) transactional externalities, which refer to the frequent and recurrent exchanges of information and knowledge between local actors; iv) Jacobian externalities, linked to the urban dimension (Pugas; Calegary; Antonialli, 2013).
Externality of agglomeration	These externalities arise as constituted groups benefit from the action in a cluster. They refer to impacts resulting from contact between companies, producing knowledge spillovers (Boudreaux; Meiners, 2019; Weston; Siu; Johnson, 2001; Wheaton; Lewis, 2002).
Subject producing externalities	An economic subject exerts an external influence on another economic subject, and this external influence cannot be bought or sold at the market price (Shen; Ye; Zhu, 2018).
Subject receiving externalities	The externality is used to indicate certain benefits or costs of an action that go beyond those considered by the decision-maker (Shen; Ye; Zhu, 2018).
Externalities of internal economies to firms	Unforeseen effects capable of reducing the internal costs of the firm (Huang; Hong; Ma, 2020)
Marshall-Arrow-Romer Externalities (MAR)	It assumes that an externality is linked to learning, and this is the basis of economic growth, related to specialization (Henderson, 1997; Huang; Hong; Ma, 2020).
Externalities of Jacobs	It assumes that an externality is linked to learning, and this is the basis of economic growth, related to specialization (Henderson, 1997; Huang; Hong; Ma, 2020).
Externalities of the urban network	They occur between different cities and industries and are provided by interconnection (Huang; Hong; Ma, 2020).
Technological externalities	Refers to production costs, which are obtained through nonmarket transactions, such as labor or resource savings resulting from better organization or production methods, acquired through factors related to knowledge flows (Boudreaux; Meiners, 2019; Johansson, 2005).
Pecuniary externalities	They may occur through market transactions or interorganizational ties. They are advantages in the purchase, such as quantity discounts in the purchase of raw materials (Boudreaux; Meiners, 2019; Johansson, 2005).

Source: own elaboration.

Given the above, it is important to understand the concept of major hazard installation (MHI), organizations associated with high impact risks, and that produce positive and negative externalities for surrounding territory.

Major hazard installation (MHI)

The concept of major hazard installations (MHIs) refers to technical units of high complexity, where large quantities of dangerous substances and energy are produced, processed, handled, discarded and stored (Silva; Gunasekera; Alwis, 2017; Shaluf, 2007; Shanmugam; Razak, 2021). De Silva, Gunasekera and de Alwis (2017) add that this concept includes all equipment, structures, pipes, machines, tools, private railway branches, docks, and unloading docks that serve the installation, docks, warehouses or similar structures necessary for the operation of this facility.

According to Khudbiddin et al. (2018), for several years, there has been a concern with the causes of serious dangers, their identification, risk assessment and their management process from a global perspective, aiming to protect the environment, human beings and heritage. A few measures need to be considered by these industries in terms of management and safety for businesses, lives, properties and the environment. Failure to consider the appropriate criteria selected may result in major accidental hazards (MAHs).

Major accident risks (MAHs) are defined as an incident involving the loss of life that occurs inside or outside the area with injuries and/or an incident involving the release of toxic chemicals or explosion or fire or spillage of hazardous chemicals that results in emergencies or damage to equipment that lead to process interruption or that have adverse effects on the environment, impacting workers, the public and the environment (Khudbiddin et al., 2018).

In this sense, it is understood that the complexity of MHIs can result in failures (in design, components, equipment and processes), and the interactions between these failures can result in accidents with the potential to generate loss of life, damage/injury to individuals and adverse effects on the environment (Silva; Gunasekera; Alwis, 2017; Khudbiddin et al., 2018; Shaluf, 2007). Failures of an organization in the control of material risks usually result in a man-made disaster called a technological disaster (Shaluf et al., 2003).

Some types of MHIs are refineries, petrochemical and chemical production plants, water treatment plants, tailings dams, nuclear power plants, and other types of power plants, among others (Shaluf, 2007). As an example of this concept, mining companies, despite environmental degradation and the risks associated with tailings dam ruptures, tend to play a central role in the economies of states and municipalities (Mancini; Sala, 2018).

Mancini and Sala (2018) argue that the benefits derived from mining include the characteristic of being one of the main generators of raw material essential for the performance of the global economy and support for the well-being of the population. Moreover, this activity is responsible for the generation of thousands of direct and indirect jobs with high economic profitability (Instituto Brasileiro de Mineração, 2021). In addition, the authors state that job creation (both in the mining sector and indirectly in different sectors) is a positive impact of mining activity documented in several studies, both at the local and national levels. These aspects become even more critical when the mining activity is developed in economically dependent communities, with few possibilities for economic diversification (Mancini; Sala, 2018), where the generation of jobs, income and local revenue are centered on mining (Gomide et al., 2018).

METHODOLOGY

In this section, the methodological procedures used to conduct this study are presented.

Regarding the approach, the study can be classified as quantitative, since the creation of the vulnerability factor, statistical estimation and inference techniques will be used, involving factor analysis and the Propensity Score Matching (PSM) model, to estimate the effect of the presence of mine tailing dams.

Data description

Heckman et al. (1997) and Dehejia and Wahba (1999) argue that omitting important variables can increase the bias in the outcome estimates. Thus, only variables that positively or negatively influence the results should be included. Thus, the variables used in this study are shown in Box 3.

Socioeconomic variables related to the vulnerability and economy of the municipality were selected to explain how they impact the territory. Subsequently, differences tests were performed with the variable GDP per capita and with the variable vulnerability factor.

For the composition of the sample, all the municipalities of Minas Gerais were selected, and those for which there was no information available about some of the variables used were excluded. This resulted in 837 municipalities, of which 58 have ore tailings dams (i.e., established mining companies).

Factor Analysis

Factor Analysis was used to reduce the database variables to a single factor, grouping those that were correlated with each other.

Cannon and Muller-Mahn (2010) developed a framework with dimensions of vulnerability and admit that this concept has complex characteristics produced by the combination of factors derived especially from class, gender and ethnicity, in addition to including health-related factors. Based on this logic, the following variables were used: i) PEA older than 14 years; ii) gender; iii) percentage of children under 14 years of age; iv) percentage of those over 60 years of age; v) infant mortality rate; vi) dependency ratio; vii) 15 to 24 years of age who do not study/work; viii) percentage of dependent vulnerable people; ix) percentage of self-reported whites; x) percentage of people with inadequate water and sewage supply; xi) rate of illiterate individuals aged 15 years or older; xii) rate of extremely poor individuals up to 14 years; xiii) schooling rate of 6 to 14 years; and xiv) hospitalizations.

The principal component and varimax rotation method were used, which explains the maximum variance of the column. In addition, missing cases, and the coefficients with values lower than 0.40 were excluded. For the operationalization of the analysis, SPSS version 20 software was used.

Box 3: Variables

Variables		Source
Objective Function (Probit)		
Dams or not	0 if there is no dam; and 1 if there is a dam	National Agency of Water and Sanitation (2021)
Covariate		
PEA older than 14 years	Economically active population, 14 years old or older	IBGE, 2010 Population Census
Gender	Percentage of men in the municipality	IBGE, 2010 Population Census
Children under 14 years old	Percentage of population under the age of 14 in the municipality	IBGE, 2010 Population Census
Older than 60 years	Percentage of the population aged 60 years or older in the municipality	IBGE, 2010 Population Census
Infant mortality	Infant mortality rate	DATASUS/2010
Dependency ratio	Dependency ratio	IBGE, 2010 Population Census
15 to 24 years old who do not study/work	People aged 15 to 24 years who do not study, do not work and are vulnerable	PNAD (2017)
Vulnerable people dependent on the elderly	Vulnerable people dependent on the elderly	PNAD (2017)
White	Portion of white population (white population/total population)	IBGE, 2010 Population Census
People with inadequate water and sewage supply	People with inadequate water supply and sewage	IBGE, 2010 Population Census
Illiterates aged 15 years or older	Percentage of illiterates among the population aged 15 years or older enrolled in the Single Registry (2017)	PNAD (2017)
Extremely poor up to 14 years	Percentage of children up to 14 years of age who are extremely poor	IBGE, 2010 Population Census
Schooling from 6 to 14 years	Schooling rate among the population aged 6 to 14 years	IBGE, 2010 Population Census
Hospitalizations	Portion of the hospitalized population (number of interactions/total population)	DATASUS/2021
Population	Total municipal population	IBGE, 2010 Population Census
Formal jobs	Formal jobs (logarithmic)	RAIS/2018
Demographic density	Demographic density of the municipality (logarithmic)	IBGE, 2010 Population Census
MHDI	Municipal human development index	PNUD/2010
Relative jobs	Part of the employed population (number of employed persons/population)	RAIS/2018
Result		
GDP per capita	Gross Domestic Product per capita	SIDRA/2018
Vulnerability factor	Result of the factor analysis of the vulnerability components	Constructed by the authors

Source: own elaboration.

Propensity Score Matching (PSM)

Quasi-experimental models are designed to uncover the presumed effects of certain causes. They are valuable for assessing the impact of an intervention on a variable of interest, allowing for counterfactual inferences about what would have occurred in the absence of the intervention (Cook; Campbell; Shadish, 2002). Among the most used techniques for non-randomized experiments are Propensity Score Matching (PSM) and Synthetic Control Method (SCM), which are employed to estimate the causal effects of a treatment (Caliendo; Kopeing, 2008; Han; Shi, 2017).

In this study, given the available data, the PSM method was chosen, as used by Balanay and. Yorobe (2014) and Doloriel and Cortez (2022). This decision was made because the SCM requires temporal data both before and after the intervention (Abadie et al., 2015). In the case of the technological disaster under analysis, there is insufficient socioeconomic data over time to establish a historical series, considering the variables presented in Table 3. To discuss the positive externalities generated in territories with the presence of mining MHIs, it is essential to estimate the effect of dams on the installed sites. Thus, the propensity score matching (PSM) methodology, which measures the impact of dams on the territories and aims to compare the control and treatment groups is used. Therefore, this methodology seeks to homogenize the distribution of several variables between groups. The Propensity Score integrates an anticipated probability of an individual from the respective group - treatment or control - being observed in the other group, according to the observed characteristics. Thus, the group of counterfactuals is estimated, which will be the basis for matching.

In this study, the treatment group is defined as municipalities with dams, and the control group is municipalities that do not have dams.

The PSM is based, among other things, on the following question: what would happen to the individuals who received the treatment if they had not received this treatment (or the other way around)? In other words, one seeks to estimate an "individual", which represents the observed individual if he or she was in the treatment group.

Thus, the municipality has two potential products:

- Y_{1i} if the individual i is treated: $D_i = 1$;
- Y_{0i} if the individual i is not treated: $D_i = 0$.

Thus, the treatment effect is defined as:

$$\Delta_i = Y_{1i} - Y_{0i}$$

It is also assumed, according to Caliendo and Kopeinig (2008), that the average treatment effect of interest is the average treatment effect (ATT), defined as:

$$\tau ATT = E(\tau \mid D = 1) = E[Y(1) \mid D = 1] - E[Y(0) \mid D = 1]$$

In addition, the PSM methodology starts from some identification assumptions, such as the independence assumption ($Y_1, Y_0 \perp D$)). From this assumption, the following conditions should apply:

$$E\{Y_{0i}|D_i = 0\} = E\{Y_{0i}|D_i = 1\} = E\{Y_{0i}\}$$

$$E\{Y_{1i}|D_i = 0\} = E\{Y_{1i}|D_i = 1\} = E\{Y_{1i}\}$$

$$E\{Y_{0i}|D_i = 1\} - E\{Y_{0i}|D_i = 0\} = 0$$

Thus, the parameter of interest can be estimated:

$$\theta = E\{\Delta_i|D_i = 1\} = E\{Y_{1i}|D_i = 1\} - E\{Y_{0i}|D_i = 0\}$$

One of the parameters of the *propensity score* is that it is possible to observe the control and treatment groups with a substantial overlap. Therefore, the following is the *propensity-score* formula:

$$P(x) = \Pr[D = 1|X = x]$$

where *P(x)* is defined as the conditional probability of participating in the treatment given the characteristics of the individual *(x)*. In the case of the present study, the analysis is as follows: territories with companies that have mine tailings dams exhibit more externalities than those without such activities. To estimate the propensity score, this study uses the binary response model with the *probit function.* Consider a class of binary response models:

$$P(y = 1|x) = G(\beta_0 + \beta_1 X)$$

where *G* is a function assuming values strictly between zero and one, and *G* is the standard normal cumulative distribution function, which is considered an integral:

$$G(z) = \Phi(z) \equiv \int_{-\infty}^{z} \phi(v)dv$$

where $\phi(z)$ is the standard normal density. The choice of *G* ensures that the probability of being treated is between zero and one.

Finally, for the operationalization of the PSM, the software Stata (version 16) was used, which is a complete and integrated statistical software package that provides analysis and management of data, graphs and many statistical resources, such as linear regression, cluster analysis, and effects of treatment.

ANALYSIS AND DISCUSSION OF RESULTS

The results will be presented in the following order: results of the factor analysis, the results of the probit model, result of the difference tests with the GDP *per capita* and result of the difference tests with the vulnerability factor. Then, they will be discussed and interpreted.

Vulnerability factor: factor analysis

To group the vulnerability variables into factors, the one-factor solution presented the requirements for performing the factor analysis (Hair; Anderson; Tatham; Black, 2005), with KMO greater than 0.6 (0.721), and the test of Bartlett's sphericity was significant (p <0.01). Table 1 presents these results.

Table 1: Factor analysis: KMO and Bartlett test

Kaiser–Meyer–Olkin Measure of Sampling Adequacy.		0.721
Bartlett's Test of Sphericity	Approx. Chi-Square	7298.437
	Df	91
	Sig.	0.000

Source: own elaboration.

This model showed 36.42% of the explained variance, as shown in Table 2.

Table 2: Factor analysis: Total variance explained

Component	Initial eigenvalues			Extraction of sums of square loads		
	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
1	5.099	36.422	36.422	5.099	36.422	36.422
2	1.518	10.846	47.268			
3	1.323	9.451	56.719			
4	1.205	8.609	65.328			
5	1.006	7.185	72.513			
6	0.817	5.832	78.345			
7	0.724	5.171	83.516			
8	0.670	4.789	88.304			
9	0.493	3.523	91.827			
10	0.389	2.778	94.606			
11	0.283	2.022	96.627			
12	0.259	1.847	98.474			
13	0.210	1.497	99.971			
14	0.004	0.029	100.000			

Source: own elaboration.
Legend: extraction method: principal component analysis.

The components of the single factor are shown in Table 3. The following variables were included: dependency ratio; extremely poor up to 14 years; less than 14; white; infant mortality; people in households with inadequate water and sewage; PEA older than 14 years; and illiterates who are 15 years or more.

Table 3: Matrix components and factor loadings

	1 component
Dependency ratio	0.902
Extremely poor up to 14 years	0.877
Children under 14 years old	0.864
White	-0.771
Infant mortality	0.768
People with inadequate water and sewage supply	0.747
PEA older than 14 years	-0.712
Illiterates aged 15 years or older	0.59

Source: own elaboration.

Thus, once the factors were extracted, a new variable was generated in the database, called the vulnerability factor, which was used for the next steps.

Externalities: Propensity Score Matching (PSM)

Initially, a general model was used, in which all the variables listed in Table 3 were included. However, the variables population; gender; older than 60 years; children under 14 years of age; infant mortality; dependency ratio; 15 to 24 years old who do not study/work; vulnerable people dependent on elderly individuals; people with inadequate water and sewage supply; extremely poor up to 14 years; schooling from 6 to 14 years; hospitalizations; formal jobs; and demographic density were not significant.

Subsequently, some collinearities were identified, such as dependency ratio and demographic density, 15 to 24 who do not study and do not work and are illiterate, extremely poor children up to 14 years of age and PEA over 14 years, formal jobs and relative jobs. After the significance and collinearity analysis, some variables were eliminated, and the resulting specific model, which is the basis for the PSM, is shown in Table 4.

Table 4 shows the estimates of the *probit model,* with marginal effect. First, it is necessary to analyze the significance of the variables. The variables population, GDP *per capita* and vulnerability factor were significant for the model, considering a significance level between 5% and 10%.

In this sense, the fact that the municipality has an MHI is related to following variables: population, GDP *per capita* and vulnerability factor. The data indicating MHDI and relative jobs were not significant; that is, they are not related to the presence of mining companies with dams.

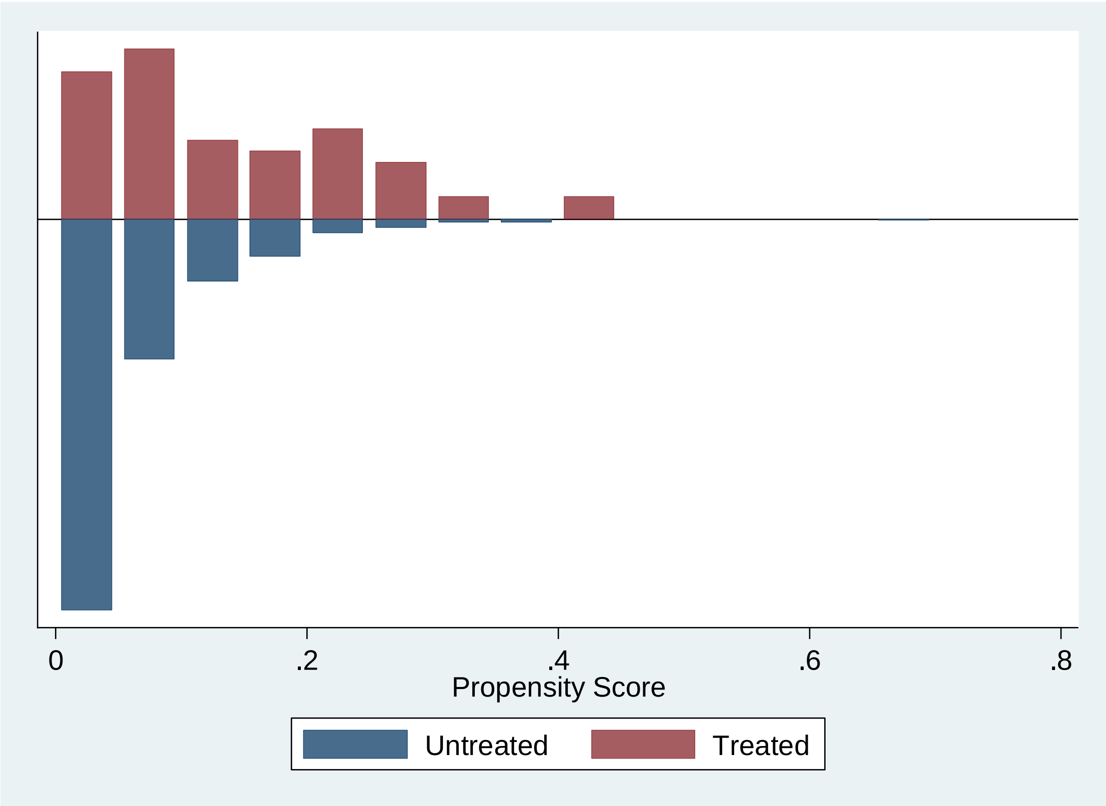
Table 4: *Probit* model

Variables	Coefficient	Standard error	Z	P> | z |
Population	0.1934	0.0694	2.79	0.005
GDP *per capita*	1.1061	0.1886	5.86	0
MHDI	-2.2867	1.6012	-1.43	0.153
Relative jobs	-1.5464	1.1822	-1.31	0.191
Vulnerability factor	0.1772	0.1022	1.73	0.083
Number of observations = 755				
Pseudo R^2 = 0.2019				

Source: own elaboration.

Graph 1 shows the results of the matching for the control and treatment groups, that is, municipalities with mining MHIs and those comparable ones without them. The upper part of the graph shows the estimated probability distribution for the treatment group (municipalities with mining MHIs), while the lower part shows the probability distribution for the control group. The matching achieved was reasonable, with minor divergence at the end of the graph.

Graph 1: Matching results



Source: own elaboration.

Next, the results of the PSM are presented, and the algorithm chosen for this work is kernel *matching*. *Kernel matching* (KM) is a nonparametric match estimator that uses weighted averages of all individuals in the control group to construct the counterfactual result. It can be seen as a weighted regression of the counterfactual result in an interception with weights given by the kernel weights. These weights depend on the distance between each individual in the control group and the counterfactual estimate (Caliendo; Kopeinig, 2008). When using KM, it is necessary to choose the kernel function and the *bandwidth*, that is, the interval in which observations will be used for comparison. In this study, an interval of 0.1 was used. Differences tests will be performed considering GDP *per capita* and vulnerability factors as result variables.

Initially, from the *probit* presented in Table 4, the difference test was performed with the GDP *per capita variable,* as shown in Table 5.

Table 5: Bootstrap *results - GDP* per capita

	Coefficient	Standard error	Statistics of Z	P> | z |
R (TTA)	0.3479	0.0456	7.63	0.000
Replications: 50				

Source: own elaboration.

The results of Table 5 suggest that the municipalities that have mining companies in their territory have a higher GDP *per capita* than those that do not. The difference between the GDPs *per capita* in municipalities with mining MHIs was significant (at the 1%) and positive (0.34% more).

Considering the vulnerability factor as an outcome variable, derived from the *probit* in Table 4, the results are shown in Table 6.

Table 6: Bootstrap results - vulnerability factor

	Coefficient	Standard error	Statistics of Z	P> | z |
R (TTA)	-0.2182	0.0753	-2.90	0.004
Replications: 50				

Source: own elaboration.

Thus, the establishment of these companies in the territory decreases vulnerabilities by 0.21%, a significant difference at 1%. Although mining MHIs seek to establish themselves in more vulnerable locations, they tend to reduce these vulnerabilities in the territory after their establishment. Increases in income (measured here by GDP *per capita)* generate a reduction in vulnerabilities.

Regarding the population variable, the findings of Barreto (2001) corroborate the results of this study, since they indicate that there was demographic growth in most of the municipalities analyzed by him after the establishment of mining companies.

The results confirm the estimates made by Santos (2021) that the GDP has a positive relationship with the presence of mining companies, i.e., the existence of these companies is associated with a location with higher GDP. According to the author, the establishment of these organizations is related to an increase in GDP. Lima and Teixeira (2006) found that mining is an important component of the economy in the selected municipalities, occupying a large portion of the territory's GDP.

According to Cunha *et al*. (2019), the positive results in the economic field are measured by the production and commercialization of mineral goods, the supply of jobs and the generation of revenue for the public coffers through taxes and royalties. In addition, ore extraction and processing positively influence social development (Cunha et al., 2019).

Despite the tendency of these companies to establish themselves in more vulnerable locations, these vulnerabilities are mitigated after their establishment. Considering that in most studies the concept of vulnerability is associated with income (Alwang; Siegel; Jorgensen, 2001; Pritchett; Suryahadi; Sumarto, 2000; Wisner, 2016), the expected relationship is that income increases (GDP *per capita*) will generate a reduction in vulnerabilities.

FINAL CONSIDERATIONS

The existence of MHIs is commonly associated with contradictory impacts, given the risks and environmental degradation associated with the presence of these facilities. This study aimed to estimate the difference between municipalities with and without dams based on socioeconomic data and to verify the effect of the presence of these industrial organizations in the territory on GDP *per capita* and on the territorial vulnerabilities.

The results showed that whether the municipality has a mining company or not, it is related to the variables population, GDP *per capita* and vulnerability factor. Corroborating the theory, which states that territories with mining companies have a stimulating effect on their GDP, the findigs also suggest that municipalities with the presence of these organizations have a higher proportion of GDP, and the establishment of these companies is associated with the reduction in existing vulnerabilities at the site.

The identification of these externalities allows a better evaluation by public managers about the benefits of the activity. The installation of a mining company with tailings dams can be an instrument for fostering local development. Therefore, regulatory proposals and government policies should be oriented to reduce, mitigate, and even eliminate the potential negative impacts from the activity and to promote economic development. These externalities should be considered and weighed together for the decision to establish such organizations in a location.

In general, the results corroborate most of the existing studies, as income increases are a positive impact of mining activity (Lima; Teixeira, 2006; Santos, 2021), which consequently reduces local vulnerabilities. In addition, this study contributes to a topic that is not substantially explored in the literature, especially in the Brazilian context, since there is no consensus on the effects of mining on the development of the territory (Denes, 2018).

Despite its contributions, this study acknowledges several limitations. For the operationalization of the software, it was necessary to group the variables along the vulnerability axis using factor analysis to reduce the size of the database.

Per capita GDP is an indicator widely used in the literature for assessing socioeconomic risk. However, it has limitations as it exclusively evaluates the economic aspect, which can be obscured by income concentration (Damásio; Mah, 2011; Rodrigues, 2018). Furthermore, the results are specific to the context in which they were analyzed and cannot be generalized.

For future studies, it is recommended to apply this study in a broader national or international context; evaluate the degree of industrial concentration of the sector; use other vulnerability variables as outcome; verify the negative externalities related to the environmental context in the presence of these companies; and replicate this study to territories with the presence of other types of MHIs.

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