Regional Economic Resilience and Mining in the State of Minas Gerais/Brazil: the barriers of productive specialisation to formal employment and tax management

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Abstract
This article aims to analyse the vulnerability of mining municipalities in the State of Minas Gerais especially as regards the fiscal and employment, affected by recent external shocks. To this end, indicators of resistance and recovery were calculated from employment data in order to measure the economic resilience of economies dependent on mining. Dynamic Panel Data estimation was performed to understand the relationship of the labour market with variables related to the commercialization of iron ore and the collection of CFEM from municipalities. The results indicated that the price of iron ore has a positive relationship with employment, showing that external shocks that affect the sale of the product can directly affect employment in these locations. Furthermore, the collection of CFEM proved to have a negative relationship with the labour market, which suggests that the weak management of this collection is one obstacle to local socio-economic development. The results showed the low resilience of the municipalities analysed, which makes them more vulnerable to shocks of different types, magnitudes and scales.
Key words: Regional Economic Resilience; Mining; Generalized Moments Method (GMM), Minas Gerais/Brazil

Resumo
Este artigo tem como objetivo analisar a vulnerabilidade econômica dos municípios mineradores do Estado de Minas Gerais, especialmente quanto à perspectiva fiscal e do emprego, frente aos recentes choques externos. Para tanto, indicadores de resistência e recuperação foram calculados, a fim de mensurar a resiliência econômica dos municípios dependentes da mineração. A estimação por Dados em Painel Dinâmico foi realizada com a finalidade de entender a relação do mercado de trabalho com variáveis relacionadas à comercialização do minério de ferro e arrecadação de CFEM dos municípios. Os resultados indicam que o preço do minério de ferro tem relação positiva com o emprego, mostrando que choques externos que atinjam a comercialização do produto podem afetar diretamente o emprego nessas localidades. Por outro lado, o recolhimento da CFEM mostrou ter relação negativa com o mercado de trabalho, o que sugere que possíveis problemas de governança sejam um dos entraves ao desenvolvimento socioeconômico local. Tais resultados evidenciaram a baixa resiliência dos municípios analisados, o que os tornam mais vulneráveis aos choques de diversos tipos, magnitudes e escalas.
Palavras-chave: Resiliência Econômica Regional; Mineração; Método Momentos Generalizado (GMM), Minas Gerais/Brasil

1 – Introduction

The understanding of how regional economies respond, adjust themselves, develop, and evolve in the face of disturbances has been the object of analysis by economists and geographers focused on regional economic resilience (BOSCHMA, 2015; MARTIN, 2012; MARTIN; SUNLEY, 2015; PIKE; DAWLEY; TOMANEY, 2010; SIMMIE; MARTIN, 2010). Employing this literature, researchers try to understand the different development trajectories, the structural, economic, and institutional features, the limitations of a region, as well as how those factors affect the capacity for regional reconversion. They also seek to analyse how the characteristics of regional productive structures are affected by external and/or internal macroeconomic shocks, as in European countries (FRATESI; RODRÍGUEZ-POSE, 2016; MARTIN et al., 2016) or Brazil (SILVA, 2018; SILVA; SILVA; TUPY, 2019; TUPY; CROCCO; SILVA, 2018).

However, studies involving economic resilience and mining regions are still incipient in the international literature and also in Brazil. Based on this framework, Silva (2018) highlights that the end of the growth boom in the Brazilian mineral extraction sector, stimulated by the increase in Chinese demand, was one of the causes for some of the mining-based Brazilian municipalities to experience fiscal imbalances. The lower profitability of iron ore production, caused by the drop in product prices starting in 2013, led to a loss of tax collection, which was not offset by the strategy of adjusting production costs carried out by mining companies in order to maintain the volume of exports. One of the main impacts of this commercial loss was the reduction in the payment of the Financial Compensation for the Exploitation of Mineral Resources (CFEM) where the mining activity is present.

Although the mining extractive activity is important for the municipalities where it occurs, mainly because it increases the volume and scope of tax collection, financial return, as well as expansion of both local direct and indirect investments (ENRÍQUEZ, 2007), it can be an obstacle to local development. According to Enríquez (2007), mining alone does not overcome two substantial challenges in the sustainable development process - job creation and equity guarantees in the allocation of benefits among generations.

By analysing some Brazilian mining municipalities in the States of Minas Gerais and Pará, Gonçalves (2014) and Enríquez (2007) evidenced that the mining activity alone cannot guarantee the execution of good management practises of its financial and tax resources offering possibilities to generate positive externalities in the locations benefited by those resources and contributing to the planning of local development strategies. Gonçalves (2014, p.5) points out that in addition to mining resources being exhaustible, which compromises the access of future generations to this asset, there is a chain of negative consequences related to environmental and urban problems. The lack of sustainable planning and adequate infrastructure in mining municipalities also generates negative local externalities, reinforcing the importance of planning product-level activities that are less dependent on mining.

Given this context, the objective of this article is to study the effects of short-term external shocks on the formal labour market in municipalities in the State of Minas Gerais, Brazil, specialised in iron ore extraction. For the theoretical discussion, the evolutionary regional economic resilience literature was adopted, concerning the structural characteristics of the region, its institutions, and *path dependence* (BOSCHMA, 2015; PIKE; DAWLEY; TOMANEY, 2010). Such features help to understand the transmission of shocks and condition the recovery of those locations regarding different shocks and the need to think about economic development strategies.

Therefore, this article is structured as follows: Section 2 provides a brief theoretical review of the literature on evolutionary regional economic resilience. Section 3 presents the discussion on productive specialisation and the obstacles to economic diversification, emphasizing the importance of the public sector as both a manager of the resources generated by mining activities and a planner of productive diversification strategies. Section 4 describes cyclical elements, especially the effects of international trade, the trade balance, the mining sector, and the mining labour market, exposing its importance for the State. Section 5 analyses the economic resilience of the 33 most prominent municipalities in collecting the CFEM royalties in 2017 in Minas Gerais, according to the National

Mining Agency (ANM). Aiming to measure the economic resilience of the selected municipalities, following Martin (2016), resistance and recovery indicators were calculated for the periods of rises (*booms*) and falls (*busts*) of formal employment in the State, between 2002 and 2016. Next, the Dynamic Panel method was used to examine the relationship between the labour market in those municipalities and variables linked to foreign trade of iron ore, such as the CFEM prices and collection. To conclude, the final considerations are presented.

2 – Regional Economic Resilience: an Evolutionary Approach

The concept of resilience involves the capacity of a system to recover after being hit by shocks or disturbances, with either transient or permanent effects, maintaining its functionality (PIKE; DAWLEY; TOMANEY, 2010; SIMMIE; MARTIN, 2010). Studies on regional economic resilience are relevant to understand the behaviour of different systems and scales (local, regional, national), with an interdisciplinary approach, through the interaction with historical, social, environmental, institutional, and demographic elements, enabling a more comprehensive knowledge of development trajectory of the localities.

In the evolutionary typology, the concept of balance is refuted and focuses on the potential to reconfigure a structure, especially in the long term (BOSCHMA, 2015), considering several resources, the regional economic structure, and the local embeddedness (KITSOS; CARRASCAL-INCERA; ORTEGA-ARGILÉS, 2019), as well as capacities, competencies, and stakeholders at different levels and scales (SENSIER; BRISTOW; HEALY, 2016). Thus, regional economic resilience is a region's capacity to support long-term development combined with its positive response to short-term shocks. This approach concentrates on the evolution of the regions and the capacity to adapt and restructure industries, technologies, institutions, considering the economy as a historical and contingent process. Therefore, it is impossible to predetermine multiple equilibria, even though their existence may only be an *ex-post* empirical issue (MARTIN; SUNLEY, 2015).

Hence, the capacity to respond to shocks must consider how they affect the potential of the regions when developing new growth ways. In the long run, new trajectories brought about by new industries or technological advances that can be created or renewed must be taken into consideration, provided that they are different from the preconceived development paths (BOSCHMA, 2015).

Although this study examines the resilience of mining economies in the face of the shock of falling iron ore prices, understanding the characteristics and consequences of the shock region and how it affects the territory leads to the question of adaptation and adaptability, relevant from an evolutionary perspective. For Dawley, Pike and Tomaney (2010), adaptation is a movement towards a preconceived path in the short term, characterised by strong and rigid links among social agents in the locality, which can explain a form of resilience based on a preconceived and previously successful development path. Adaptation depends on the trajectory defined by the region's industrial legacy and the possibility of reorienting the skills, resources, and technologies transferred by the ancestors.

In turn, adaptability explains a different type of resilience that can manage unforeseen events. By means of adaptability, resilience arises from opportunities or decisions to leave a successful path in the past in favour of a new trajectory (DAWLEY; PIKE; TOMANEY, 2010). Pike, Dawley and Tomaney (2010) define adaptability as the dynamic capacity to accomplish and unfold multiple evolutionary trajectories, through (weak or strong) connexions among social agents in the region, increasing the system's capacity to respond to unforeseen changes. The authors reiterate the importance of the concepts of *path dependence*[1], *adaptation,* and *adaptability* as complex and dynamic processes, mediated by the relationship among State, capital, labour, and

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[1] In general, the most adopted conception of path dependence in Economics refers to the trajectory or previous stages in a direction, which induces even more movement in the same direction, assuring growing returns. In this case, the probability to take new steps on the same path aftershocks grows with each step taken on that path. This is because the relative benefits of the current action, compared to previously possible options, increase over time, that is, the transition costs (*exit costs*) of switching to some alternative increase. The timing of the change is also higher, so it continues performing likewise after some shock.

society, in a multi-scale institutional environment, to understand the nature, variation, and timing of changes and the post-shock trajectory.

Those concepts are necessary to understand the success (or failure) of a regional economy, especially in the long run, when its industrial, technological, labouring, and institutional structures change to adapt to competitive, technological, and market pressures, disturbances and opportunities, faced by their agents (SIMMIE; MARTIN, 2010). Adaptation and adaptability are important concepts to understand the trajectory and economic conformity of the municipalities studied, and the impacts of shocks. They also help to facilitate long-term recovery strategies, taking advantage of competencies, endogenous knowledge and legacies, as well as strategies leading to new trajectories.

Simmie and Martin (2010) conceive resilience as an "adaptive skill" since it is the competitive advantage of companies in a region, used to adapt to changes and shocks, that shapes the evolutionary dynamics and trajectories of this local economy over time. Studies like the one by Pike, Dawley and Tomaney (2010) consider a region's economic structure diversification the element that provides more economic growth and stability. According to the authors, heterogeneous and diversified economies, with trained and qualified economic agents, can achieve stronger adaptive capacity. This leads to the argument that diversified economies are more adaptable because they dispel the negative effects on a range of local economic activities rather than concentrate and reinforce them.

Validating the importance of economic diversification, Simmie and Martin (2010) argue that economic evolution depends on the actions of individual agents who can learn, innovate, and adapt their behaviour. For that reason, economic systems are never in balance. It is thus fundamental to analyse the relationship between productive diversification and regional economic resilience, which will be done next.

3 – Economic Diversification and Tax Management

The regions affected by expansive (or contractionary) shocks need to maintain their competitive advantages, whether in the short term, to incorporate displaced workers and preserve the minimum conditions of employment and income generation, or in the medium-long term, so as to absorb industries from different sectors and strengthen their competitive attributes, being able to work out new development trajectories. For this reason, two factors are fundamental to strengthen the capacity of regional economic resilience: both the productive diversification and the improvement of governance in the management of the diverse resources (fiscal, human, environmental, productive) in its different instances.

Productive diversification creates greater regional resistance to shocks than a more specialised structure, since different industries have distinct elasticities of demand, different export markets and dependence on monetary conditions (exchange rates, interest rates, debt financing), among others (MARTIN et al., 2016). For Dissart (2003), economic diversification is fundamental to the planning of local development, allows the establishment of several policies for socioeconomic well-being, increases economic stability (different economic sectors tend to reduce fluctuations in employment). A region that is more dependent on primary production or durable manufacturing of high-income elasticity may face shocks in productivity or sharp changes in prices or revenues (MARTIN et al., 2016).

For Malizia and Ke (1993), diversification is not just the lack of specialisation, but the presence of multiple specialities as sources of competitiveness, which can counterbalance when commercial cycles or external shocks occur. Diversified regions tend to be more stable than specialized ones because they can allocate the productive resources of a sector affected by a shock to other sectors, making it possible to maintain their levels of employment and local economic growth (DAVIES; TONTS, 2010). For Goschin (2019), diversification should be a key factor for resilience, as it causes regions to be more flexible to adaptability, helps to dispel risks, adapts to changes more quickly, making them deal with economic shocks or a crisis more easily.

Another fundamental aspect to promote regional economic resilience is good governance, discussed herein from the fiscal management perspective. National and international evidence of the mining extraction resources management and governance from the various instances (municipal,

state, federal) has pointed out difficulties in integrating the collection and sustainable strategies locally (ENRÍQUEZ, 2007; GONÇALVES, 2014; GRUSS, 2014; SIMONATO; MAGALHÃES; DOMINGUES, 2017; SINNOTT; NASHAT; DE LA TORRE, 2010).

Sinnott, Nashat and De La Torre (2010) reinforce evidence for countries dependent on natural resources in Latin America between the pro-cyclical response of government spending and the *booms* and *busts* of commodity prices. For the authors, while *booms* tend to accompany unsustainable increases in public sector spending, governments slowly reduce spending when it ends, mainly because of rigidity and reversal costs. According to them, problems such as corruption and rent-seeking incite private interests over public spending, that is, State resources could be used to favour political support that is not necessarily consistent with the concerns of the population.

The destination of revenues obtained from the exploitation of mining resources, such as the CFEM, is controversial and raises the hypothesis that municipalities with large collection volumes are economically dependent on the sector with the largest fiscal contribution, thus weakening the municipal budget (GONÇALVES, 2014). The increase in the collection volume considered temporary (since mining extraction is a finite activity) may limit productive diversification and expose the local economy to instabilities in the international commodities market.

The State (and its instances) has an essential role in governance because it determines the tax regime and the mining legislation that regulate the rent sharing, the allocation rules, and the rent distribution within the public sector (ENRÍQUEZ, 2007). Consequently, the management of collected resources from the mining extraction industry, *a priori*, should reduce the predictable negative effects of the activity, including the regional outcomes of the future production shutdown. However, in most of the municipalities where this activity is present, the lack of control and transparency makes it difficult to understand the effective application of the resources to the community. What is perceived, in most cases, is the lack of strategic investments that ensure more stability to the municipality in times of crisis in the sector (SIMONATO; MAGALHÃES; DOMINGUES, 2017).

4 – The Influence of the External Scenario on the Commercialization of Iron Ore in the State of Minas Gerais

Minas Gerais has always stood out on the national scene as the main producer of metallic and non-metallic minerals in the country, with iron ore being its main export product. Figure 1 shows the percentage share of products in mining exports in 2018, in which iron ore exports totalled 6.77 billion dollars (29%).

As a result of its dependence on mining, the State has suffered from constant market fluctuations due to external and internal factors affecting the production and sale of iron ore. If, on the one hand, the activity leads to competitive advantages, resources, job creation, and local linkage effects on the economy, on the other hand, the dependence on this product-level activity makes it more vulnerable to withstand recessive pressures. Therefore, some authors (GOSCHIN, 2019; SILVA; SILVA; TUPY, 2019; TAN et al., 2020) defend the importance of strategies that promote economic diversification as a way to improve the ability to adapt more rapidly to the difficulties generated by economic shocks, taking local comparative advantage of the key sectors.

During the last decade, the Brazilian economy has been hit by at least two major recessive shocks: the global financial crisis (2007-2008) and the strong political and economic instability that culminated in the 2015-2016 recession (TUPY et al., 2019). The subprime crisis, followed by the economic slowdown, reflected in the decline of both the international market and the price of commodities, in the fall in demand for Brazilian exports and the liquidity of international markets. According to those authors, the continued slowdown in international growth was added to the national political turmoil (culminating in the impeachment of President Dilma Rousseff), whose instability generated reinforced the Brazilian economic crisis[2].

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[2] For an analysis of macroeconomic conditions, especially after the 2008 financial crisis, see Barbosa Filho (2015). For an analysis of Brazilian economic situation and the labour market performance, see Baltar e Leone (2015).

Figure 1 – Exports of Minas Gerais (2018)
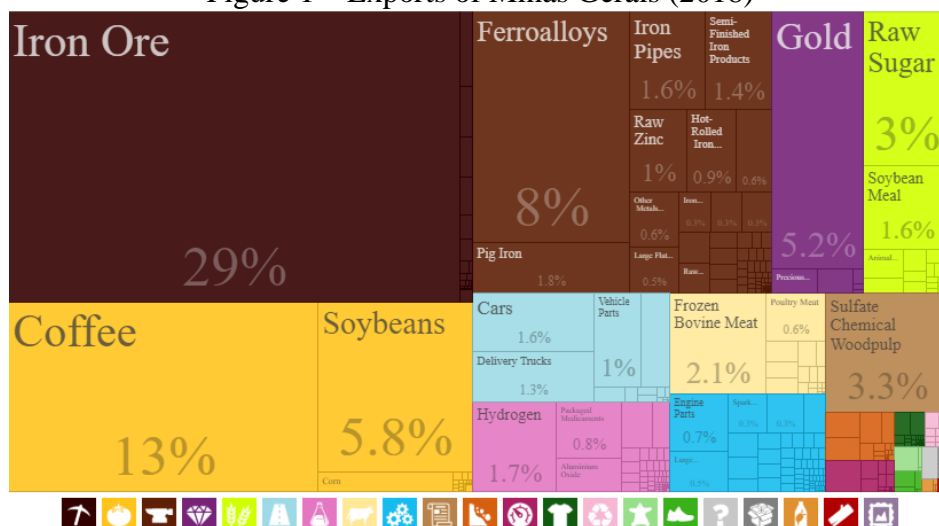
Exchange rate fluctuations, changes in external demand, deterioration in relative prices and competition in international supply influenced the decision-making level of production by mining companies that, as a means of faster adjustment, reduced their costs, impacting in employability in the sector and others directly related to it (SILVA, 2018). Internal shocks resulting from the political and economic instability of recent years have also directly impacted the mineral extraction industry, which has also affected employability and tax collection in the State and the mining municipalities. The start of S11D project operations in Canaã dos Carajás, in the State of Pará, for example, shifted investments to the North of the country, leading it to exceed the volume of exports of the product concerning Minas Gerais (VALE, 2019). Also, the socio-environmental disasters resulted from the disruption of both the Fundão dam in Mariana and the B1 dam in Brumadinho caused deaths, serious social, environmental, and economic impacts on the State.

The exposure of the Minas Gerais economy to variations in the international commodities market, especially on the sale of iron ore, can be seen in the graphs that follow. Shocks that meet the demand and volume of exports also cause fluctuations in the product value, which reduces the amount of taxes passed on to the municipalities, in addition to affecting the labour market. The gradual decline in commodity prices as of 2011, valid in 2013 (after a long upward cycle), led those prices to be carefully monitored, especially in Latin America, since the revenues derived from those products finance a significant part of public budgets and import costs. Falling prices have had an impact on public finances and the external accounts of commodity-exporting economies in the region (GRUSS, 2014).

The fall in iron ore price reflects the effect of the worsening external and internal economic conditions, the reduction in Chinese demand. In response to this shock, the mining companies initiated a strategy of reducing production costs (facilitated by the expansion of their mining units) to counter financial losses, caused by falling iron ore prices, favoured by the exchange rate behaviour. The evolution of iron ore prices, between 2005 and 2018, suggests that the Brazilian mineral extraction industry faced a strong devaluation of the product as of 2011 (Graph 1).

Graph 2 shows that the exported *quantum* followed a fall in prices. It is possible to note that exports and imports evolved in similar proportions, but always maintaining the positive balance driven by the increase in exports. In 2009, the effects of the 2008 financial crisis affected the trade balance. However, as of 2010, there was an increase in exports from the State, followed by a continuous fall beginning in 2011, due to the effects of reduced Chinese demand, the adaptation of the portfolio of mining companies given the devaluation of iron ore, and the rupture of the Fundão dam in Mariana (SILVA, 2018; SIMONATO et al., 2017).

Graph 1 – Iron ore price in US dollars (2005 – 2018)
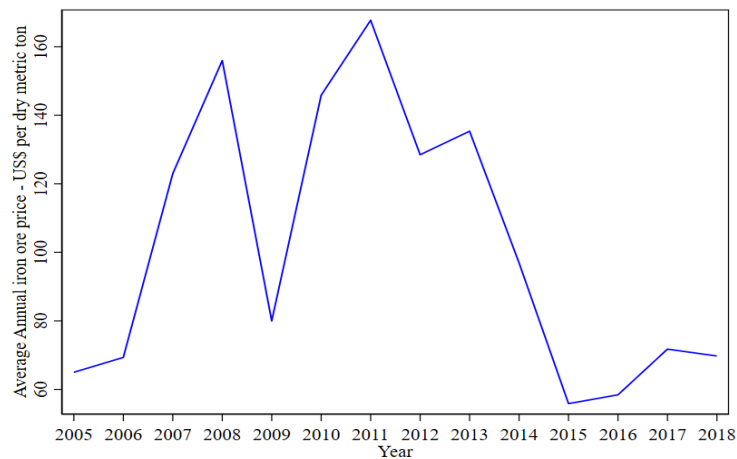
Graph 2 – Minas Gerais Trade Balance (2005 – 2018)
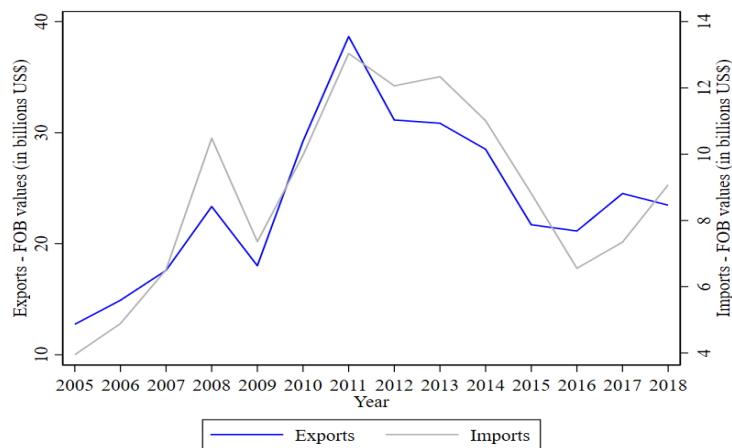
The socioeconomic effects generated by those shocks culminated in economic losses, particularly in tax revenues and contributions, worsening fiscal imbalances. According to Barbosa et al. (2019), turnover growth retracted sharply between 2015 and 2018, but expenses continued to grow above inflation, despite the attempt to contain public spending and investment retraction. The result was growing deficits and, in the case of the states with the largest share of the manufacturing industry, the duration and magnitude of the crisis were even more severe.

As mentioned before, the participation of Minas Gerais in the international iron ore market is quite significant, and the taxes arising from this market are of great importance in the State's revenues. The decrease in commodity prices led, for example, to a reduction in the transfer of the CFEM at the federal, state, and municipal levels. However, as most of the transfer of resources (65%) is passed on to the municipalities, these were the ones that suffered the most from the effects of reducing this tax on their revenues. The relevant participation of the mining sector in the economy of those locations reinforces the thesis that the high economic dependence on mining extraction makes mining municipalities more susceptible to the negative effects of contractionary shocks that affect the sector.

Graph 3 demonstrates the evolution of employment linkages in the State of Minas Gerais and Brazil. It is possible to note that the State followed the national dynamics between 2005 and 2014. Before the first shock, the Brazilian economy was experiencing a period of robust growth due to the combination of a favourable external scenario for commodity exports and the impacts of

redistributive policies implemented as of 2003 (TUPY et al., 2019). The recessive period (2014-2016) is characterised by the reflexes of the financial crisis, highlighted by the subsequent Brazilian macroeconomic and political crisis. In Minas Gerais, the recessive impact was intensified by the boost in mining activity, as a result of the commodity market and the collapse of the Fundão dam in Mariana in 2015, and all its consequences in economic terms (reduction in employment, production, the tax collection of the state and municipalities).

Graph 3 – Evolution of Employment linkages in Minas Gerais and Brazil (1985-2018)
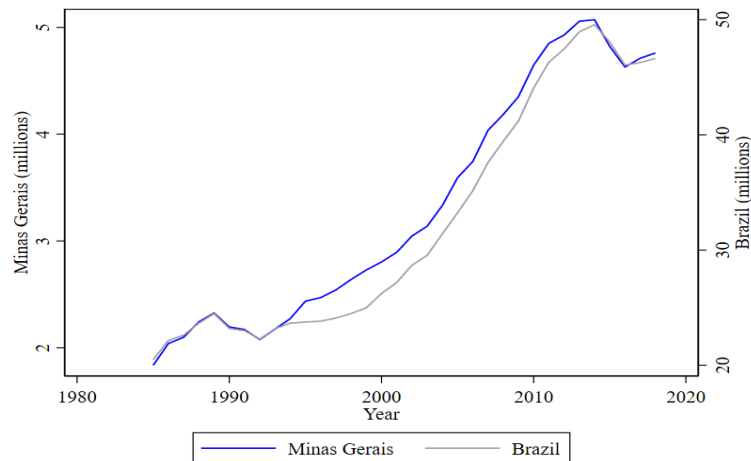
Source: Authors' own elaboration based on RAIS (2020).

When examining the spatial heterogeneity pattern in economic activity and factors related to regional disparities in Minas Gerais, Silva, Perobelli e Araújo Júnior (2020) stress that the level of municipal economic activity, geographic location and infrastructure cause important spatial spillover effects to boost the activity in neighbouring municipalities. Yet, the overflows occur differently throughout the state. Barbosa et al. (2019) note that the product structure of Minas Gerais is still characterised by the heavy weight of the chain of production of metal-mechanical inputs, associating itself as a supplier to the industrial hub centred in the States of São Paulo and Rio de Janeiro, being very vulnerable to the fluctuations in the economic cycle led by the manufacturing and construction industry. Those characteristics, the productive specialisation of the State, and the scarcity of financial resources resulting from high indebtedness and the fiscal crisis, make this economy even more vulnerable to external (and internal) shocks. Thus, this hypothesis will be tested in the empirical exercise described ahead, which will show how the economy dependence on a given sector can lead to considerable economic losses, even in the short term, concerning reduced employability, and harming the income dispersion.

5 – Methods, Estimates and Results
5.1 – Analysis of Economic Resilience

Indicators of resistance (degree of shock sensitivity or depth of reaction to the shock) and recovery (speed and degree of recovery from the shock) of 33 municipalities in Minas Gerais[3], were calculated with employment linkage data reported on the Annual List of Social Information (RAIS) in order to analyse the capacity of municipalities dependent on the mineral extraction sector to cope with the negative shock of the fall in iron ore prices. Following Martin et al. (2016), the strategy

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[3] From the largest collector to the lowest: 1- Nova Lima, 2- Congonhas, 3- Itabira, 4- São Gonçalo do Rio Abaixo, 5- Mariana, 6- Itabirito, 7- Conceição do Mato Dentro, 8- Brumadinho, 9- Ouro Preto, 10- Belo Vale, 11- Catas Altas, 12- Itatiaiuçu, 13- Rio Piracicaba, 14- Sarzedo, 16- Alvorada de Minas, 17- Bela Vista de Minas, 18- Desterro de Entre Rios, 19- Antônio Dias, 20- Mateus Leme, 21- Piracema, 22- Barão de Cocais, 23- Passa Tempo, 24- Igarapé, 25- Oliveira, 26- Mário Campos, 27- Rio Acima, 28- Itaúna, 29- São Joaquim de Bicas, 30- Caeté, 31- Sabinópolis, 32- Sabará, 33- Araxá, 34- Santa Bárbara. The 15th municipality, Belo Horizonte, was excluded from the sample, because it was confirmed as a municipality with variables that differ from the standard of the others in the generation of standardised waste for the identification of outliers.

proposes measures of resistance and regional recovery to investigate the effects of recessive shocks. The choice of municipalities was based on the 'Largest CFEM Collectors Report', released by ANM (2020), with the sale of iron ore in 2017.

Those indicators have been used in the literature (GUAN et al., 2018; MARTINI, 2020; SILVA, 2018; SILVA; SILVA; TUPY, 2019), and allow an examination of how different regions were affected by a common shock. Based on a type of reaction (resistance and recovery) of the national economy, in economies considered equal, the real variables were expected to contract (recession) or expand (recovery) at the same rate as the national economy. Thus, Martin et al. (2016) define the expected change in employment in a region r given a recession or recovery, in k periods, according to the equation (1):

$$\left(\Delta E_r^{t+k}\right)^e = \sum_i g_N^{t+k} E_{ir}^t \tag{1}$$

where $\sum_i g_N^{t+k}$ is the contraction or expansion rate of national employment, and E_{ir}^t is the employment in industry i in region r at the initial time t (base year), which is the turning point for recession or recovery. The left side of the equation (2) represents the employment change in region r from period t.

To measure the resistance or recovery of a region, the authors used equations (3) and (4), respectively:

$$Resis_r = \frac{\left(\Delta E_r^{Recession}\right) - \left(\Delta E_r^{Recession}\right)^{expected}}{\left|\left(\Delta E_r^{Recession}\right)^{expected}\right|} \tag{2}$$

$$Recov_r = \frac{\left(\Delta E_r^{Recovery}\right) - \left(\Delta E_r^{Recovery}\right)^{expected}}{\left|\left(\Delta E_r^{Recovery}\right)^{expected}\right|} \tag{3}$$

The measurements in equations (2) e (3) are centred at zero, by definition. As a result, a positive value of $Resis_r$, for example, shows that a region is more resistant to recession. Thus, it would be less affected by a crisis in relation to the national economy. If the result is negative, the region is less resistant. Consequently, it would be more affected by a given recession.

According Martin et al. (2016) combinations of resistance and recovery indicators that point to possibilities of resilience. Most mining municipalities are expected to be in the upper right quadrant (good strength and good recovery capacity), or lower right (weak resistance and good recovery capacity). In the latter case, the municipalities would be resilient, showing good recovery, despite the low capacity to respond immediately to the shock. This assumption is due to the fact that the mining activity is finite, and that, in general, those municipalities have received a good tax collection and contributions, which should be directed to the enhancement of structural conditions (productive diversification, improvement of infrastructure, education, health etc.). Also, this practise would supposedly enable municipalities to recover from any contractionary shocks.

Graph 4 shows the recovery (2002-2013) and resistance (2014-2016) indicators for the expansive and recessive employment cycles of the 33 selected municipalities in Minas Gerais[4]. The periods of recovery and resistance were defined based on the evolution of employment in the State (Graph 2). It is possible to notice an increase in hiring in the formal labour market beginning in 1992, the post-inflationary and political crisis in Brazil, followed by a fall in 2014. The years 2017 and 2018 will not be analysed herein, as it is an incomplete cycle.

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[4] The recovery indicator is calculated from 2002, which is the initial year of the available series, due to the unavailability of data on the total number of employment contracts by municipality in RAIS in the recovery period that began in 1992.

Graph 4 - Recovery (2002-2013) and Resistance (2014-2016)
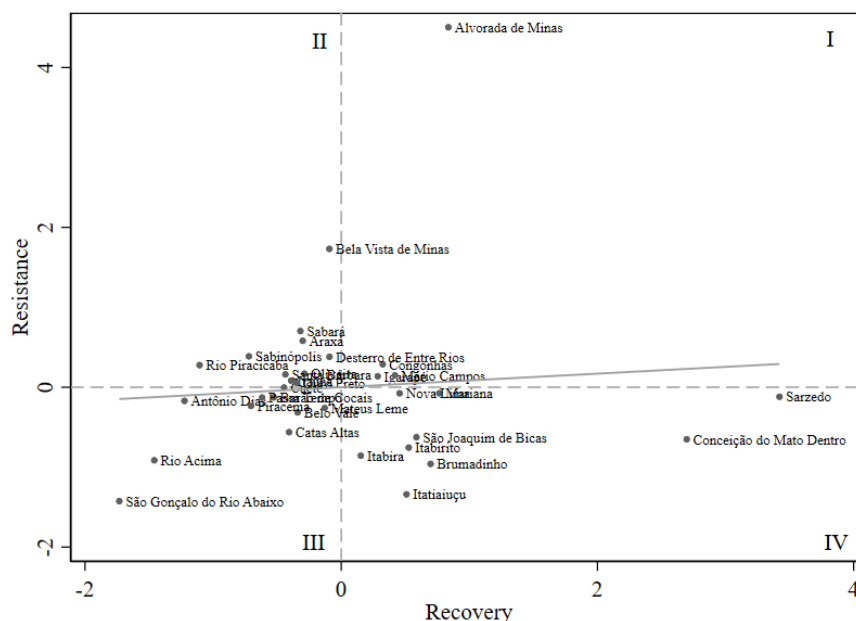
Source: Authors' own elaboration.

In general, most municipalities clearly showed values close to zero in terms of both resistance and recovery indicators. It reveals that those municipalities show a degree of stagnation of shocks, despite the expressive volume of tax collection. Nevertheless, they have the resources to invest in policies and programs that offer more economic diversification and human capital formation, for instance. This reveals that there were no structural changes that would enable institutions, business structures, and the labour market to adapt, providing a reorientation of skills, resources, and technologies to more dynamic sectors not dependent on mining. The result suggests that the resources management derived from iron ore extraction has been ineffective by not creating strategies that would ensure greater economic stability when the key sector of the municipality is hit by a shock.

Four of the five largest CFEM collectors in Minas Gerais in 2017 (Nova Lima, Congonhas, Itabira, São Gonçalo do Rio Abaixo, Mariana) are in quadrants II and IV, as expected. São Gonçalo do Rio Abaixo, unlike the others, was in quadrant III. It is worth mentioning that together these municipalities represented 33.8% of the employment linkage in the sample in 2017.

According to Graph 4, Nova Lima, Itabira, Mariana (quadrant IV) presented weak resistance and good recovery, and Congonhas (quadrant II) performed good resistance and recovery, which means the municipalities were more resilient to the fall in iron ore price, demonstrating more stability in the labour market. Conversely, since they are the major iron ore exporters of the State, the plants of these mining companies often receive investments aimed at expanding their operations[5], which results in more employability in the sector and, therefore, in the civil construction industry.

Besides that, with the loss of profitability in the commercialization of ore, in general, the companies implemented processes to reduce production costs to avoid layoffs (SILVA, 2018). Among the municipalities analysed, Mariana and Nova Lima should be highlighted. In the case of Mariana, part of the good recovery may be related to jobs preserved by determining compliance with the Term of Transaction and Adjustment of Conduct (TTAC), an agreement signed by dozens of entities, including federal, state and municipal bodies; the companies Samarco, Vale and BHP

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[5] Between 2012 and 2014, the "Fourth Pellet Project" (*Projeto de Quarta Pelotização* - P4P) was implemented at the Germano Open Pit Mine, owned by Samarco mining company in Mariana. However, the expansion of production capacity was interrupted with the collapse of the Fundão dam in November 2015. Nova Lima and Congonhas are municipalities that own mines acquired by Vale, in the mid-2000s, from the companies Ferteco and MBR.

Billiton; representatives of the basin committee. The agreement established guidelines on how to repair the damage caused by the rupture of the Fundão dam – job preservation, layout schemes, reconstruction works (FUNDAÇÃO RENOVA, 2020). Due to its proximity to Belo Horizonte (the capital city of Minas Gerais), Nova Lima has a relatively more diversified economy compared to the other municipalities. However, the low resistance capacity is linked to the lack of structural changes capable of expanding the supply of human capital, diversification strategies etc., and capable of increasing the resilience of those municipalities.

São Gonçalo do Rio Abaixo has the largest open pit mine in Minas Gerais, the Brucutu Mine, owned by the company Vale S/A, which had its service life expansion projects started in 2015 (ÉPOCA NEGÓCIOS, 2015). Therefore, the low recovery of the municipality (-1.73) suggests the influence of the public administration sector that acts according to the municipal electoral cycle. As in several mining municipalities, this sector is the one that most employs formal labour. By analysing the evolution of employment based on RAIS data, it is observed that in the years of municipal elections in 2008, 2012 and 2016, the total number of linkages fell to 43%, 11% and 37.5%, respectively. However, in the post-election periods, the resumption of employment in the sector overcame such losses, implying the adherence of local job offers (related to this sector) to the political cycle. The national political cycle as well as the national and Minas Gerais recessive scenario also interfered in the restriction of resources for the continuity of infrastructure works and the promotion of sectorial programs, which is reflected in the following data. The low resistance (-1.42) of the municipality may be related to the reduction of 1,159 jobs between 2014 and 2016. The loss of employment linkages occurred mainly in the sectors of public administration (381), agriculture (281), and civil construction (341).

Beginning from the analysis of the outliers Alvorada de Minas, Bela Vista de Minas, Conceição do Mato Dentro, Rio Acima and Sarzedo, the recovery and resistance factors are related to the implantation or expansion projects of mining companies. Alvorada de Minas and Conceição do Mato Dentro stand out as positive outliers, and this result is due to the start of activities by the mining company Anglo American, which has a mining area between the two municipalities. Alvorada de Minas performed a recovery indicator of 0.8, and resistance of 4.5. The justification for this high resistance value may be associated with the increase of employability in the municipality between 2011 and 2013. During this period, the Anglo American started the works of the Minas-Rio Project, with the emergency recovery of the State highway MG-010, due to poor road conditions and the need to flow inputs for the project's implementation works (ANGLO AMERICAN, 2018). Thus, the increase in total employment in the municipality was mainly in the civil construction sector.

On the other hand, Conceição do Mato Dentro experienced an increase in formal employment started in 2013 and intensified in 2015. This explains the high recovery (2.69) and low resistance (-0.65) rates of the municipality. The employment growth was observed in the civil construction sectors and mainly in the mining industry, due to the works and the start of operations of the company Anglo American.

The municipality of Sarzedo (metropolitan region of Belo Horizonte) also experienced an increase in employment linkages in the mining sector, which means a high recovery capacity (3.42). This increase was more accentuated after the acquisition of the mining company Itaminas Comércio de Minérios S.A. by the Eastern Chinese company Bureau of Mineral Exploration and Development in 2011 (MARCONDES, 2010), leading to the expansion of its operations. According to the mining company, 90% of its workforce is made up of Sarzedo residents (ITAMINAS, 2020).

The exploration of iron ore by ArcelorMittal Mining is also responsible for the increase in formal employment in Bela Vista de Minas, which started in 2015 and characterized the municipality with a high resistance capacity (1.73). This increase may be related to the beginning of the expansion plan called Projeto Itabiritos at Mina do Andrade, which includes new iron ore processing facilities. According to the company, 360 direct and indirect jobs aimed at the exclusive purpose of implementation of the new plant would be created, prioritizing local labour hiring from Bela Vista de Minas and João Monlevade (ARCELORMITTAL, 2020).

Finally, Rio Acima stands out as a municipality with low recovery (-1.45) and low resistance (-0.91) rates. It receives CFEM transfers in response to Federal Law 13.540/2017 (ANM,2020a), which has caused cities that suffer from the impacts of mineral extraction activity in their vicinity to be reimbursed, since they are affected by mining production, as well as the production area. In this case, formal employment in Rio Acima does not suffer impacts related to mining extraction, but the municipality is among the largest collectors in Minas Gerais, especially next to Nova Lima, the largest collector in the State.

Hence, the mineral extraction sector is important for municipalities, creates jobs in related sectors, but makes the economic and labour market dynamics very dependent on the activity, and vulnerable to shocks (external and internal) to the Brazilian economy. The next section will address the relationship between the labour market and variables related to iron ore commercialization and the CFEM collection of in those municipalities.

5.2 - Analysis of the determinants of formal employment

This article uses the Generalized Method of Moments (GMM) that was designed (ARELLANO; BOND, 1991; ARELLANO; BOVER, 1995; BLUNDELL; BOND, 1998; HOLTZ-EAKIN; NEWEY; ROSEN, 1988) to solve problems of consistency of the estimators. Two general estimators designed for situations with "small-T, large-N" panels were particularly observed. This means that there are few periods of time but several individuals; with independent variables not strictly exogenous, with fixed effects; and with heteroscedasticity and autocorrelation within individuals (ROODMAN, 2009).

It is important to highlight the difference between the results of the GMM in one and two stages. Both one step and two steps approaches are consistent, but the latter is more asymptotically efficient. However, the two-step GMM estimator also experiences a low sampling bias of the asymptotic standard errors estimated in linear models (DORDMOND, 2017). This is because asymptotic standard errors do not regard the extra variation in small samples due to the parameters estimated in the weight matrix (WINDMEIJER, 2005). The author presents a solution by proposing a bias correction method and, therefore, making the two-stage GMM estimation method the best choice. This article follows the same approach.

To complete the analysis, the results of other estimators will be presented: Pooled OLS, Fixed Effects, and GMM First Difference. It is important to note that the Pooled OLS estimator overrates the coefficient for the lagged dependent variable, while the Fixed Effects estimator undervalues the coefficient (Nickel bias). Therefore, the GMM coefficient of the lagged dependent variable must be between the estimated coefficients of Pooled OLS and the Fixed Effects when calculated with the differences of the GMM estimator. If this is the case, the estimator is stable.

The total number of employment linkages (*lnlink*) is the dependent variable in this work. The independent variables are:

- Financial Compensation for the Exploitation of Resources (*lncfem*) - ANM
- Nominal Wage (*lnwage*) - RAIS
- Iron Ore Price (*lnprice*) - INDEXMUNDI
- Number of employees holding a higher education diploma (*lnsup*) - RAIS
- Dummy for Alvorada de Minas, Conceição do Mato Dentro and Sarzedo, outliers in the resilience analysis (*d_out*)

The following econometric model is then estimated:

$$lnlink_{i,t} = \beta_0 + \beta_1 \, lnlink_{i,t-1} + \beta_2 lncfem_{i,t} + \beta_3 lnwage_{i,t} + \beta_4 \, lnprice_t + \beta_5 lnsup_{i,t} + \beta_6 d\_out + \alpha_i + \varepsilon_{i,t} \qquad (4)$$

It is possible to test the individual or joint significance hypothesis of the coefficients of Equation (4), and the results for both are presented using the t-test of individual significance, and the F-test of joint significance, respectively. In addition, other important tools in the GMM

methodology are the Hansen test for instrument exogeneity and the AR (2) test for non-correlated residues. The Hansen test supports a null hypothesis that the instruments are not correlated with the error term and, therefore, the instruments are appropriate for the estimation, *i.e.*, they are exogenous. The AR test (2), in turn, advocates a null hypothesis that the residual dummies are correlated in second order. By construction, it is expected that the residuals are indeed correlated in second order, suggesting the appropriate construction of the estimation and the instrument matrix.

5.3 – Empirical results and discussion

This subsection will present and discuss the empirical results obtained in the above-mentioned estimation, to assess the relations of the selected independent variables with formal employment in economies dependent on the mineral extraction sector. Table 1 shows the results of the Pooled OLS, Fixed effects, GMM First Difference and GMM System estimates, as well as the specification and autocorrelation tests.

The results of the GMM-System estimation demonstrate that lagged total employment linkages variable ($lnlink_{i,\ t-1}$) has a positive, but not significant, coefficient. This means that the number of people employed in the formal market in the previous period has a positive effect on the next number, as expected, given the expansive cycle of the Brazilian economy (between 2004 and 2013), which had an impact on the labour market (BALTAR; LEONE, 2015)[6]; investments made in the sector, carried out by expansion projects - especially in the civil construction area - complementary to mining activities and strongly absorbing labour (SILVA, 2018). Despite this, the result for the municipalities analysed was not significant, suggesting that the less favourable conditions of the most recent period, marked by the deterioration of the economic and fiscal environment, the cooling of investments by the public and private sectors and the earlier implementation of expansion projects affected the municipality's employability more intensely.

The collection of CFEM (*lncfem*) has a negative coefficient and is not significant. This variable is added as a control to check whether the collection of a municipality has an impact on the labour market. Municipalities with a higher volume of revenue could offer more jobs, since the scenario can generate more investment from the public (and private) sector, especially through the financing of public policies and infrastructure works that, in some way, promote improvements and mitigate the negative externalities of mining activity, boosting the local economy. Unlike expectation, this negative CFEM coefficient does not confirm this hypothesis, which may demonstrate low efficiency in the use of the revenues generated by mining in order to promote the municipality's continued development. The fact that there is no positive effect of royalties on the labour market of mining municipalities may also suggest poor resource management in public policies, especially in economic activities that promote the diversification of their production bases, improving job offers and employment conditions.

As expected, nominal wage (*lnwage*) has a positive and meaningful effect on the labour market of mining municipalities. In addition to the effects of the previously highlighted economic situation, from 2004 to 2013 there was an increase in the formalization of jobs and the value of the minimum wage. There was also an increase in the participation of formal employment in various establishments that absorbed previously informal labour, especially in the civil construction field (BALTAR; LEONE, 2015). The same authors point out that, in the period examined, participation in total employment in establishments and occupations requiring higher education increased (Ibid, p. 63). Another result also reflected it. The total number of staff with complete higher education in the municipalities (*lnsup*) shows how education has positive and substantial effects on employment. Besides that, it tends to affect the resilience capacity of the municipalities analysed in a positive manner as a long-term project.

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[6] These authors point out that despite the sectors in which there was greater competition with production from other countries, there was an increase in business structuring and in the degree of wage and formalization of the labour market, such as in the processing industries, as well as in the mining extraction segment and the public utility sector (Ibid, 2015, p. 59).

Table 1 – Model estimation results
Variable dependent on models: Total Employment linkages *(lnlink)*

Independent variables	OLS Pooled	Fixed Effects	GMM First Difference	GMM *System*
lnlink$_{i,t-1}$	0,239***	0,031	-0,359***	0,087
	(4,23)	(0,50)	(-6,34)	(0,74)
lncfem	-0,019	0,032	-0,035	-0,015
	(-0,86)	(0,68)	(-0,52)	(-0,91)
lnwage	0,514***	-0,011	-0,146	0,528***
	(5,86)	(-0,09)	(-1,11)	(5,23)
lnprice	0,320**	0,010	0,154	0,251*
	(2,37)	(0,07)	(0,91)	(1,89)
lnsup	0,113	0,010	0,109	0,173**
	(1,37)	(0,11)	(1,18)	(2,59)
d_out	0,014	7,49***		0,055
	(0,07)	(3,63)		(0,28)
cons	-3,431***			-2,548**
	(-3,53)			(-3,37)
Observations	299	299	263	299
R^2	0,641	0,593		
Groups			32	33
Instruments			16	20
Sargan test			0,000	0,000
Hansen test			0,311	0,191
AR(1)			0,212	0,023
AR(2)			0,017	0,203

Significance level *** p <0.01, ** p <0.05 and * p <0.1. T test in parentheses.
Source: Authors' own elaboration.

Concerning the independent dummy variable of interest, the hypothesis was that the iron ore price on the world market (*lnprice*) would have a positive effect on the employability of a mining municipality. This variable had a positive coefficient and was statistically significant, which confirms the hypothesis. The positive relationship between employment and iron ore price is associated with the incentive in production, by companies, when the price of ore increases. This incentive in production requires hiring labour, which has a positive effect on employment rate, mainly due to the maintenance of infrastructure and services (highly employing sectors) directly and indirectly related to the region's economic activities.

The result of the estimation shows that municipalities dependent on mining are vulnerable to external shocks that affect the sector, which reflects a relatively low level of resilience, in agreement with other studies (SILVA, 2018; TAN et al., 2020). In other words, the mineral extraction industry does not guarantee the analysed municipalities a competitive advantage beyond the activity, either to absorb industries from different sectors, or to incorporate workers displaced from the mineral extraction sector, which reinforces the importance of economic and productive diversification (GOSCHIN, 2019; KITSOS; CARRASCAL-INCERA; ORTEGA-ARGILÉS, 2019; SILVA; SILVA; TUPY, 2019; TAN et al., 2020).

Finally, the dummy used to identify the municipalities that best performed resilience and recovery capacity in the analysis made in subsection 5.1 was positive, but not significant. This result is in accordance with the analysis of the resilience executed for those municipalities. For the whole series of those locations, it is clear that the boost in job vacancies is due to the recent start of mining activity there or to mining expansion projects, which does not yet reflect a long-term dependence with the sector, like the other municipalities in the sample.

The results confirm the hypothesis that economies dependent on mining are susceptible to fluctuations in the foreign market, especially to the commodity price. This influence gives them low

economic resilience in the face of shocks that affect this sector. In addition, they suggest that an external shock affecting the iron ore commercialization could impact the local labour market negatively. Hence, efficient resource management is important regarding the use of resources generated by mining, directing them to economic diversification projects.

6 – Conclusion

The discussion on regional economic resilience analyses the capacity of regions to resist to, recover from and adapt to shocks. For the study proposed in this article, the short-term effects were examined, due to the shock of falling iron ore price from 2013, in Minas Gerais. Even though the analysis is focused on the short term, understanding the effects of the shock is related to the characteristics of the product structure and its economic, historical and institutional trajectory, which indicates the importance of thinking about how those factors affect the present and may condition future trajectories of the State economy.

The empirical analysis of this work started from the calculation of resilience and recovery indicators, as a way of measuring the economic resilience of 33 municipalities in the State of Minas Gerais, Brazil, that received the largest amounts of the CFEM in 2017. The results showed that a large part of the municipalities had a low resilience capacity due to the shock of falling iron ore prices. Also, the municipalities reacted positively to such shock. This may be related to the fact that, during the period studied, those locations were inserted in processes of implementation or expansion of operations related to the mining sector, which generated positive short-term effects in the business market. However, this does not involve, for example, economic diversification strategies, human capital development policies, and investments in culture and health, factors that can give greater economic resilience to those locations.

Starting from the most relevant factors for the characterization of the macroeconomic scenario of the last fifteen years and the sectorial characteristics of the State, the empirical strategy of Dynamic Panel was adopted in order to verify the relationship between the total employment ties in mining municipalities, the price of iron ore, and the collection of taxes generated by the sector, hoping to find a positive relationship between price, taxes and the labour market.

As a result, it was found that the iron ore price variable was significant and had a positive impact on employment in the mining municipalities selected for the study. Another important result was the negative relationship between the CFEM collection and the dependent variable (labour market). The sign of this relationship was not the expected when the empirical exercise was proposed, which suggests problems in governance, especially concerning fiscal and the CFEM management, compromising the municipality's ability to reinvest those resources in structural improvements (education, health, infrastructure, productive diversification), aiming at the long term, when mines are exhausted and closed. To this end, it is necessary to define public (and private) policy strategies aimed at encouraging economic activities that promote the diversification of their product bases and alleviate socioeconomic problems in the localities.

Thus, advances in this investigation should reinforce the importance of mapping new possibilities for the development of product-level activities that expand the capacity to have endogenous income in the very municipality and outline new steps to induce economic growth. In addition, more information should be added regarding the governance and/or resource management of the locations, since the results of this work suggest that the poor management of the resources generated by mining may be an obstacle to the development of the capacity for economic resilience where such activity is present.

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