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The role of foreign direct investment and regional absorptive capacity on economic complexity: A Brazilian investigation

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ABSTRACT

This study investigates how Foreign Direct Investment (FDI) and regional absorptive capacity (AC) shape economic complexity at the municipal level in Brazil, an emerging economy characterized by structural heterogeneity. Using regional export data and a manually constructed FDI proxy, we apply Feasible Generalized Least Squares (FGLS) and panel threshold regression to examine the relationship between FDI, AC, and the Economic Complexity Index (ECI). The findings demonstrate that both FDI and AC positively influence regional economic complexity; however, the relationship is non-linear. Specifically, FDI enhances economic complexity only in municipalities that surpass a minimum AC threshold, underscoring the conditional nature of the benefits of foreign investment. Robustness checks confirm the reliability of the results despite the relatively limited number of observations. These findings carry important policy implications: attracting FDI alone is insufficient to foster regional productive sophistication without parallel investments in human capital, infrastructure, and innovation capacity. Policymakers should prioritize sectors with existing capabilities and design integrated FDI strategies aligned with local productive structures to support sustainable and diversified economic growth. By providing novel municipal-level evidence from Brazil, this study contributes to the literature by highlighting the critical moderating role of absorptive capacity in the FDI–economic complexity nexus.

1. Introduction

Foreign Direct Investment (FDI) is widely recognized as a key driver of economic development, contributing to capital accumulation, technological diffusion, and productivity growth (de Mello, 1999; Hansen and Rand, 2004; Iamsiraroj, 2016; Kalai and Zghidi, 2019). More recently, research has focused on the role of FDI in shaping the productive structure, diversity, and capabilities of economies. As Kannen (2020) emphasizes, examining how a country develops the ability to produce sophisticated goods and expand product diversification is often more informative than relying solely on GDP growth or Total Factor Productivity (TFP). For instance, while the efficient production of low-complexity goods such as potato chips may raise regional TFP, economic sophistication is better captured through indicators of product complexity, distinguishing between the production of potato chips and computer chips.

Economic complexity (EC) has thus emerged as a central concept to capture the knowledge and capabilities embedded in productive systems. According to Hausmann et al. (2013), EC reflects the set of activities that economies can undertake by combining diverse knowledge bases in areas such as marketing, finance, technical development, and human resources. Two key dimensions are diversity, which refers to the

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range of products in a country's export basket, and ubiquity, which indicates the number of countries exporting a given product (Hidalgo and Hausmann, 2009). Economies producing a wide array of complex, non-ubiquitous goods are generally more resilient, innovative, and prosperous in the long run (Cristelli et al., 2015; Sepehrdoust et al., 2019). Producing technologically sophisticated, non-ubiquitous goods (e.g., x-ray machines or nanochips) typically requires the recombination of highly specialized skills and knowledge (Balland and Rigby, 2017; Balland et al., 2020). By contrast, producing ubiquitous or naturally scarce goods, such as diamonds or uranium, does not necessarily indicate high economic complexity. From this perspective, innovation is a driving force of societal advancement and wealth creation, as complex economies are characterized by broad and diversified export portfolios with fewer ubiquitous goods (Hausmann et al., 2013; Hidalgo and Hausmann, 2009; Gala et al., 2018; Sepehrdoust et al., 2019; Kannen, 2020).

The economic complexity approach in developing economies is particularly challenging due to their structural heterogeneity (Sun et al., 2015). Several scholars emphasize that host-country capabilities and local environments critically shape FDI outcomes, placing absorptive capacity at the center of this discussion. Absorptive capacity refers to the ability to recognize, absorb, and apply new knowledge (Cohen and Levinthal, 1989; Damijan et al., 2013; Girma, 2005; Görg and Greenaway, 2003; Haskel et al., 2007; Kim, 2015; Ubeda and Pérez-Hernández, 2017). High absorptive capacity increases the likelihood that regions will benefit from FDI.

Within this framework, FDI is often considered a critical mechanism for advancing productive sophistication in emerging economies, as it facilitates technology transfer, innovation, and managerial improvements (Ali et al., 2023; Sultana and Turkina, 2020). FDI spillovers may occur horizontally or vertically through linkages with local suppliers, competitive pressures, training, labor mobility, or investment in skilled personnel (Blomström et al., 2001; Javorcik et al., 2018; Sari, 2019; Griffith et al., 2017; Olsson and Frey, 2001). Nevertheless, the extent to which these benefits materialize depends heavily on local conditions, particularly the absorptive capacity (AC) of host regions, which is the ability to recognize, assimilate, and apply external knowledge (Cohen and Levinthal, 1989; Girma, 2005; Moralles and Moreno, 2020). High levels of AC strengthen the likelihood that foreign knowledge and practices will translate into regional productive upgrading (Damijan et al., 2013; Görg and Greenaway, 2003; Haskel et al., 2007; Kim, 2015; Ubeda and Pérez-Hernández, 2017).

Despite this recognition, important gaps remain in the literature. Most existing studies analyze the impact of FDI at the national level or focus on broad productivity outcomes, overlooking the role of AC in shaping regional heterogeneity in economic complexity (Nguyen and Su, 2021; Ascani et al., 2020). Empirical evidence on the interaction between FDI, AC, and EC is particularly scarce in large and heterogeneous countries such as Brazil, where industrial structures, institutional quality, and innovation capabilities vary widely across municipalities (Ferraz et al., 2020; Hidalgo, 2021). Furthermore, little is known about the threshold levels of AC necessary for FDI to promote economic sophistication at the subnational level effectively (Sun et al., 2022).

These gaps in the literature raise several important questions. *What is the impact of foreign direct investment (FDI) and absorptive capacity (AC) on productive structure (i.e., economic complexity)? More specifically, how does the interaction between FDI and AC influence economic complexity at the municipal level, particularly in heterogeneous countries such as Brazil? Furthermore, is there a threshold level of AC that regions must achieve in order to effectively leverage foreign investment to enhance their productive sophistication?* In this sense, this study investigates the relationship between FDI, AC, and economic complexity at the municipal level in Brazil. To address the scarcity of reliable regional FDI data, we construct a novel database that proxies inflows using export data and manual classification of foreign firms. Methodologically, we employed panel data techniques, including Feasible Generalized Least Squares (FGLS), as well as tested endogeneity through instrumental variables models, and panel threshold regressions to address heteroskedasticity and non-linearities.

By investigating these questions, we challenge the conventional assumption that FDI offers uniform benefits and contribute to a more nuanced understanding of the conditions under which FDI fosters regional structural transformation in emerging economies. In practice, foreign firms may collaborate with local suppliers to share knowledge and technology, improve input quality, and stimulate product innovation. They can also enhance competition, which in turn fosters innovation (Javorcik et al., 2018). Moreover, multinationals often invest in skilled labor, provide training, and promote labor mobility (Blomström et al., 2001; Sari, 2019), generating both horizontal and vertical spillovers. Aggregating diverse economic activities through inward FDI is equally relevant, as it enables recombination of products and knowledge (Griffith et al., 2017; Olsson and Frey, 2001). In this way, multinational activity may expand regional knowledge bases, contributing to improvements in economic complexity (EC).

Recent trends reinforce the relevance of this research. Emerging markets such as Brazil, China, and India are attracting increasing foreign R&D investments despite persistent challenges (Gala et al., 2018; Papanastassiou et al., 2020). While historically concentrated in advanced economies, this movement now includes developing countries, where institutional fragilities and industrial decline, such as Brazil's de-industrialization and fiscal competition, raise questions about FDI's real contribution to growth (Cypher, 2015; Mattos et al., 2017; Nunes and Nunes, 2000; Silva, 2019). Evidence suggests that FDI can promote innovation and that higher AC magnifies these benefits (Moralles and Moreno, 2020; Nguyen et al., 2018; Nguyen and Su, 2021). Understanding how these mechanisms affect economic complexity is critical, since economic sophistication is essential for economic development (Gala et al., 2018; Hausmann et al., 2013; Kannen, 2020). A regional perspective allows us to capture the differentiated effects of FDI and AC across heterogeneous contexts.

This article presents several contributions. First, at the theoretical level, it advances the literature on foreign direct investment (FDI) and economic complexity by demonstrating that the benefits of FDI are conditional on the absorptive capacity (AC) of host regions, thereby refining the understanding of how local capabilities mediate structural transformation. Second, methodologically, the study introduces an original municipal-level FDI database for Brazil and applies panel threshold regression to identify the minimum levels of AC required for FDI to positively influence economic complexity. This approach provides novel insights into the non-linear dynamics of the FDI–AC–EC nexus at a regional scale, a dimension rarely explored in the existing literature. Third, the study offers significant policy implications by showing that attracting FDI alone is insufficient to foster productive sophistication unless it is accompanied by strategic investments in human capital, infrastructure, and innovation systems. Understanding these thresholds is crucial for designing integrated industrial and innovation policies aimed at enhancing regional development in heterogeneous economies such as Brazil.

The remainder of this paper is organized as follows. Section 2 reviews the theoretical background and develops the hypotheses regarding the relationships between FDI, AC, and EC. Section 3 presents the data, variables, and econometric methodology. Section 4 reports and discusses the empirical findings, including robustness checks and threshold analyses. Section 5 concludes with a summary of the main contributions, policy implications, limitations, and directions for future research.

2. Theoretical background and hypotheses development

Economic complexity (EC) theory offers a framework for understanding how economies evolve through the advancement of productive capabilities, rather than merely accumulating resources. Initially

conceptualized by Hidalgo and Hausmann (2009), EC theory posits that economies grow by building diverse capabilities that enable the production of complex, high-value goods. This foundation builds on the idea of "product space" introduced by Hidalgo et al. (2007), which maps product relationships and demonstrates how relatedness in production can influence a nation's potential for economic diversification. Economies that produce highly complex goods, requiring specialized knowledge and sophisticated capabilities, tend to be more resilient and adaptable, positioning them favorably for sustainable growth (Cristelli et al., 2015). By analyzing an economy's output complexity, EC theory offers insights into how nations can foster resilience and competitiveness through innovation and diversification (Sepehrdoust et al., 2019).

Hausmann and Hidalgo (2009) introduced the Economic Complexity Index (ECI), which assesses a country's productive knowledge by evaluating the diversity and uniqueness of its exports. High ECI values indicate economies that produce a broad range of technology-intensive goods, reflecting a solid foundation of knowledge and capabilities. Over time, ECI has become a vital tool for evaluating growth potential and structural transformation. Hidalgo (2021) highlights ECI's role in guiding policy-making, enabling economies to identify and invest in areas that maximize returns on their productive capabilities. Furthermore, empirical applications of ECI, such as those by Balland et al. (2020) at the sub-national level, reveal how complex economic activities concentrate in large urban areas. Other studies, such as Hartmann et al. (2017), explore the links between ECI and institutional quality and income inequality, underscoring the index's applicability beyond national assessments by identifying regional strengths and gaps within diverse economic landscapes.

As scholars continue to explore the implications of ECI, a growing body of research examines how FDI might influence economic complexity by enhancing a region's productive knowledge. Through the transfer of advanced technologies, managerial expertise, and global best practices, FDI has the potential to catalyze the growth of complex, high-value industries, thus raising the economy's ECI (Javorcik et al., 2018; Nguyen and Su, 2021). Knowledge spillovers from FDI can help local firms bridge gaps between domestic practices and international standards, integrating foreign expertise into their operations and facilitating the development of sophisticated production capabilities. As noted by Nguea (2024), the effectiveness of FDI in fostering complexity depends on various factors, which can significantly influence knowledge transfer and assimilation. This research suggests that FDI's impact on ECI is not uniform; instead, it varies according to a region's existing conditions and ability to support complex economic activities through complementary resources. Ascani et al. (2020) also underscore that FDI-driven spillovers are particularly impactful in emerging economies, where establishing complex production capabilities is crucial for achieving economic stability and growth. Consequently, the dynamic relationship between FDI and ECI calls for a deeper examination of how specific regional attributes enable or limit FDI's contribution to economic complexity.

Historically, FDI has been viewed as a catalyst for economic growth, particularly in emerging markets with limited access to capital and technology (Rehman et al., 2020; Zhao et al., 2021). FDI's value has traditionally been seen in its ability to deliver immediate financial resources, technological transfer, and managerial expertise, often facilitated by multinational enterprises (MNEs) (de Mello, 1999; Hansen and Rand, 2004). By introducing more efficient production techniques and global management practices, FDI has the potential to drive productivity and technological advancement in host economies (Javorcik et al., 2018). These direct benefits have made FDI a focal point in policy discussions, promoting economic diversification and long-term growth.

Nevertheless, recent research highlights that FDI's impact is neither universally positive nor straightforward; its effectiveness varies depending on its target sectors. Papanastassiou et al. (2020) note that FDI's influence depends heavily on whether it flows into sectors capable of fostering economic complexity. In Mozambique, Timbe et al. (2024) found that FDI has primarily targeted low-complexity, resource-based industries, reinforcing dependence on these sectors and limiting economic diversification. This case illustrates that FDI's potential to increase EC is conditional on its alignment with sectors that foster complex production capabilities and contribute to structural transformation. Similarly, Ascani and Gagliardi (2020) argue that when FDI is strategically directed toward high-value sectors, its ability to drive complexity is significantly enhanced, underscoring the importance of aligning FDI with sectors that support economic sophistication.

Considering these conditional impacts, this study examines the role of FDI in enhancing ECI at the regional level within Brazil, a country characterized by diverse economic landscapes (Ferraz et al., 2020). While FDI can strengthen the production structure and support economic diversification, the degree to which it impacts EC depends on regional characteristics and the alignment of FDI with high-value sectors. Thus, we hypothesize that FDI can increase ECI, mainly when it flows into sectors with high potential for building sophisticated production capabilities. Based on these insights, we propose the following hypothesis:

Hypothesis 1. (H_1): In emerging economies, FDI strengthens the regional production structure, thereby increasing economic complexity.

However, the relationship between FDI and economic complexity is incomplete without considering the role of absorptive capacity (AC), a concept critical to understanding how regions internalize and apply external knowledge. Introduced by Cohen and Levinthal (1990), AC refers to a firm's or region's ability to recognize the value of new knowledge, assimilate it, and use it effectively. AC is essential for realizing the full benefits of foreign investments, as it enables regions to integrate external knowledge into their local production systems, enhancing competitiveness (Aldieri et al., 2018; Sultana and Turkina, 2020). Regions with robust AC can more effectively leverage advanced technologies and practices introduced by foreign firms, making AC a pivotal factor in successfully transferring and utilizing foreign expertise (Silajdzic and Mehic, 2015).

Research further suggests that AC amplifies the benefits of FDI and is a critical enabler for fostering economic complexity. Sultana and Turkina (2020) argue that regions with high AC are better positioned to facilitate collaboration and knowledge exchange between local and foreign firms, which supports the development of complex, high-value production capabilities. Nguea (2024) finds that in African economies, demographic and infrastructural factors, such as human capital and information and communication technology, are crucial for maximizing the positive impact of FDI on EC. This insight suggests that, in addition to AC, broader socio-economic conditions play a crucial role in enabling regions to capitalize on FDI, pointing to the need for integrated policies that address both AC and infrastructure development (Ascani et al., 2020; Nguyen and Su, 2021).

Acknowledging the importance of AC in enhancing FDI's impact on EC, this study examines the interaction between FDI and AC within Brazilian regions, which vary widely in terms of economic structure and capability development. Moralles and Moreno (2020) support this perspective, identifying a threshold effect whereby only regions with adequate AC can fully capitalize on FDI to increase ECI significantly. Additionally, as Nguea (2024) highlights, factors such as human capital and ICT may enhance AC, enabling regions to utilize FDI more effectively to drive economic complexity. Thus, we propose that AC moderates the relationship between FDI and EC, with regions possessing strong AC better positioned to harness FDI for sophisticated economic transformation. Based on these insights, we propose the following hypothesis:

Hypothesis 2. (H_2): The impact of FDI on economic complexity is moderated by the level of AC available in the region.

Hypothesis 3. (H_3): The impact of FDI on economic complexity is conditional on the level of absorptive capacity (AC), such that FDI exerts a positive and significant effect on EC only when regional AC surpasses a minimum threshold.

In summary, the theoretical background highlights the pivotal roles of foreign direct investment (FDI) and absorptive capacity (AC) in shaping economic complexity (EC). While FDI is widely recognized as a channel for technology transfer, knowledge spillovers, and productive upgrading, its effectiveness depends critically on the local capacity to absorb and apply external knowledge. Building on the literature on economic complexity, this study argues that the interaction between FDI and AC determines whether foreign investments translate into higher levels of EC. This framework justifies the use of econometric strategies capable of capturing both conditional and non-linear effects, which is presented in the next topic.

3. Method

To empirically examine the relationship between foreign direct investment (FDI), absorptive capacity (AC), and economic complexity (EC) at the municipal level in Brazil, this study employs a quantitative approach based on panel data econometrics. Specifically, we construct a novel municipal-level FDI proxy, integrate it with regional export and socioeconomic data, and apply Feasible Generalized Least Squares (FGLS) and instrumental variable techniques, as well as panel threshold regression. These methods allow us to account for heteroskedasticity, spatial dependence, potential endogeneity, and non-linear dynamics in the FDI–AC–EC nexus.

3.1. Data and the FDI measure

The Economic Complexity Index (ECI), proposed by Hidalgo and Hausmann (2009), will serve as the dependent variable in this study. ECI represents the economic complexity of the municipality based on its export basket. It combines, as previously explained, the complexity and ubiquity of goods a region produces, therefore representing the region's capacities.

Our independent variables are FDI and the AC. As there are no official records of regional inward FDI in Brazil, we created an FDI proxy using data from the Brazilian Integrated Foreign Trade System (SISCOMEX). Eq. (1) presents the FDI proxy.

$$FDI_{jt} = \left(\frac{MNC_{jt}}{TC_{jt}}\right) \times \sum_{i=1}^{k} W_{ijt} \tag{01}$$

where j denotes the municipality, t represents the year of analysis, MNC_{jt} is the number of multinational companies, TC_{jt} is the total number of companies, k refers to the number of foreign countries, and W corresponds to the weight measured by foreign exports (sum of exports). The indicator ranges from zero to infinity. Since SISCOMEX does not indicate whether the firms are domestic or foreign, we need to review each register to manually classify these companies. Therefore, the difficulty of obtaining FDI data at the regional level explains the small number of municipalities in our sample (Appendix A). Here, we should highlight that all exporting companies of those municipalities were checked between 2011 and 2015.

We used the GDP per capita (GDPPC) as a proxy for the region's wealth. Since higher levels of GDPPC influence the population preference for diversified goods (Elhiraika and Mbate, 2014), it is indispensable in economic complexity studies (Yalta and Yalta, 2021). The variables AGRO and IND account for the ratio of the municipality's GDP from agriculture and industry, respectively, and are intended to illustrate the regional sector configuration (Lapatinas, 2019). The density (DENS) variable was included as a control variable, as regional agglomeration influences innovation, and therefore, structural change and economic complexity (Azam, 2017). We also analyzed the number of jobs that require a college education (WQ) and should account for the complexity of jobs offered in the city (Gala et al., 2018). Furthermore, the FIRJAN Fiscal Management Index (*Índice FIRJAN de Gestão Fiscal* – IFGF) controls the institutional quality of the municipality. Appendix B provides descriptions of the variables and their sources, and Appendix C presents their descriptive statistics.

3.2. Absorptive capacity estimation

Absorptive Capacity will be both a core explanatory variable and a moderator of the FDI-ECI relation. Indeed, Girma (2005) indicates that AC is a crucial element for studies analyzing the impact of FDI on regional productivity, and here we argue that it should be considered to analyze economic complexity in Brazilian municipalities.

In this sense, Girma (2005) proposes measuring absorptive capacity (AC) through a relative total factor productivity (TFP) indicator. In this approach, each region's past TFP is divided by the highest TFP observed across all regions, resulting in a normalized measure between 0 and 1. The idea is that regions closer to the productivity frontier possess greater ability to recognize, assimilate, and apply external knowledge, thereby enhancing the benefits of foreign direct investment. Eq. (2) presents the AC measure for Brazilian municipalities.

$$AC = \frac{TFP_{it-1}}{TFP_{*it-1}} \tag{02}$$

Therefore, AC accounts for the level of success to yield the maximum TFP possible.

3.3. Econometric model and estimation strategy

To rigorously test the proposed hypotheses and quantify the relationship between foreign direct investment, absorptive capacity, and economic complexity, it is necessary to employ an econometric model and estimation strategy that can address the specific characteristics of the data and the complexities of the FDI–AC–EC nexus.

Given the structural heterogeneity of Brazilian municipalities, which exhibit wide disparities in economic size, institutional quality, and productive structures, the presence of heteroskedasticity and autocorrelation in the model residuals is expected. To address these issues (see tests in Appendix D), this study adopts the Feasible Generalized Least Squares (FGLS) method. As noted by Parks (1967), FGLS effectively corrects such problems, thereby increasing the efficiency of the estimators and improving the robustness of statistical inferences. Furthermore, to evaluate the potential issue of endogeneity, an instrumental variable model was estimated, and the Wu–Hausman test indicated no evidence of endogeneity (see Appendix E).

Eq. (3) measures the impact of FDI, moderated by AC, on EC. Furthermore, FDI lagged by one year was employed, following previous studies (Iwamoto and Nabeshima, 2012; Javorcik et al., 2018; Kannen, 2020).

$$ECI_{jt} = \beta_0 + \beta_1 X_{jt} + \beta_2 \widehat{FDI}_{t-1\,jt} + \beta_3 AC_{jt} + \beta_4 (\widehat{FDI}_{t-1} \times AC)_{jt} + \alpha_j + \quad \varepsilon_{jt} \tag{03}$$

where ECI_{jt} accounts for EC at municipality j in time t, X is the matrix of control variables, $\widehat{FDI}_{t-1\,jt}$ represents FDI one-year lagged, AC_{jt} accounts for AC, α_j represents the regional time-invariant characteristics, and ε_{it} is the residual error.

Moreover, regions require a minimum AC level to benefit from FDI. In this sense, we propose identifying the AC minimum level employing a threshold regression and testing the non-linearity in our model. Eq. (4) shows the threshold estimation method.

$$ECI_{jt} = \beta_0 + \beta_1 X_{jt} + \beta_2 \widehat{FDI}_{t-1\,jt} I(AC_{jt} < \lambda) + \beta_3 \widehat{FDI}_{t-1\,jt} I(AC_{jt} \geq \lambda) + \alpha_j + \quad \varepsilon_{jt} \tag{04}$$

where $I(\cdot)$ is the indicator function, λ is the threshold to be estimated. AC is the threshold variable while FDI is the regime-dependent predictor. The panel threshold model introduced by Hansen (2000) was applied. This method uses a set of sample quantiles (1 %, 1,25 %…98,75 %,

99 %) to estimate the threshold parameter λ. Here we tested the existence of two regimes for the effects of FDI ($H_0 : \beta_2 = \beta_3$) following Girma (2005).

4. Results

4.1. Descriptive analysis

This topic presents a descriptive analysis to explore the underlying patterns in the data. As illustrated in Fig. 1, municipalities with higher Economic Complexity Index (ECI) values typically exhibit both high levels of Foreign Direct Investment (FDI) and strong Absorptive Capacity (AC).

This pattern is observed in cities like São Bernardo do Campo and Guarulhos. Conversely, cities with low ECI scores tend to present low levels of FDI and AC simultaneously. However, some municipalities, such as Rio de Janeiro and Osasco, demonstrate similar ECI levels despite differences in FDI. This suggests that AC may be moderating in shaping the relationship between FDI and ECI. This pattern reinforces the notion that the effectiveness of FDI in enhancing economic complexity is conditional on a region's absorptive capacity. Nevertheless, FDI and AC alone do not fully account for all variations in ECI. For instance, exceptions such as Manaus, where high ECI is observed despite both low FDI and low AC, indicate the presence of other factors influencing regional economic complexity beyond those captured in our primary variables.

We also assessed whether the selected time frame was sufficient to capture meaningful variations in the Economic Complexity Index (ECI) across municipalities. Fig. 2 reveals that changes in ECI reflect shifts in a region's productive structure. This process typically unfolds gradually; it was essential to verify whether such transformations could be observed within the available data period.

The dataset spans from 2010 to 2014; however, due to methodological requirements, 2010 was used to compute the Market Index (MI), and 2011 served as the base year for the lagged FDI variable. Consequently, our econometric analysis effectively utilizes three consecutive years (2011–2013), following a similar approach adopted by Javorcik et al. (2018). Encouragingly, as shown in Fig. 2, several municipalities experienced notable changes in their ECI during this relatively short interval, supporting the validity of our empirical strategy. For instance, Porto Alegre (Rio Grande do Sul) increased its ECI from −2.36 in 2011–1.51 in 2014, while Guarulhos (São Paulo) advanced from 6.48 to 8.35 over the same period—both indicating a dynamic evolution in regional productive capabilities.

It is noteworthy that some Brazilian cities have experienced significant advancements in their productive structures. Fig. 3 highlights three municipalities that stand out in this regard.

Campinas, São Bernardo do Campo, and Guarulhos each play a distinct role in Brazil's productive structure, reflecting their specific industrial and innovation dynamics. Campinas is widely recognized as a hub of the regional innovation system, hosting major national and multinational firms alongside leading universities such as the University of Campinas (UNICAMP) and a dense network of research institutes (De Carvalho and Souza, 2025). This ecosystem fosters collaboration between academia and industry, strengthening technological development and knowledge transfer. São Bernardo do Campo, in turn, is historically linked to Brazil's industrialization and is a key center for advanced manufacturing, particularly in the aerospace sector (De Godoy, 2023). The city benefits from the presence of enterprises and its surrounding cluster of suppliers, as well as from universities, which provides a steady flow of highly qualified engineers and researchers, consolidating its role in high-tech production. Guarulhos, the largest city in the state of São Paulo after the capital, stands out for its diversified industrial base, with prominence in logistics, pharmaceuticals, chemicals, and food processing, supported mainly by its strategic location near São Paulo and the international airport (Toledo, 2011). Together, these cities exemplify the heterogeneity of Brazil's productive structure, combining innovation-driven, high-technology clusters with robust industrial and service-based economies that are essential for regional and national development.

In this context, several Brazilian cities have undergone changes in economic sophistication, as reflected in the evolution of the Economic Complexity Index (ECI). Although the absence of official municipal-level data on foreign direct investment (FDI) constrains the analysis of economic complexity, the available evidence still captures meaningful advancements across different regions. Despite the relatively short time span of the dataset, the observed variation in EC provides sufficient dynamics to support the econometric estimations.

4.2. Linear econometric findings

Table 1 reports the econometric results of the linear model estimated through Feasible Generalized Least Squares (FGLS). To better assess the effects of foreign direct investment (FDI) and absorptive capacity (AC) on economic complexity in Brazilian municipalities, multiple linear regressions were employed. Model 1 (column 1) shows that lagged FDI (FDI_{t-1}) exerts a positive and statistically significant effect on the Economic Complexity Index (ECI) at the 1 % level. Specifically, a 1 % increase in FDI leads to a 0.01294 % increase in regional economic complexity, confirming Hypothesis 1 and reinforcing the importance of FDI in fostering economic sophistication in a developing country context. In addition, Model 1 indicates that AC also has a positive and statistically significant effect on ECI, with an estimated impact of 0.06204 %, further emphasizing the role of local capabilities in enhancing productive structures. Model 2 examines the lagged effect of absorptive capacity (AC) on the Economic Complexity Index (ECI). The results reveal a positive and statistically significant relationship, indicating that an increase in AC_{t-1} is associated with a 0.15710 % rise in regional economic complexity.

Models 3–6 present the estimates for the interaction terms between FDI and AC. Across all specifications, the interaction terms are positive and statistically significant, demonstrating consistent results. These findings confirm Hypothesis 2, which posits that the effect of FDI on economic complexity is contingent upon the level of AC present in the region. Model 3 shows that when both FDI and AC are lagged by one year, the ECI increases by 0.05657 %. Model 4, which combines current FDI with lagged AC, indicates a 0.07666 % increase in ECI. The interaction term in Model 5, combining current FDI and current AC, results in a 0.09228 % rise in ECI. Finally, Model 6 reveals that the interaction between lagged FDI and current AC increases ECI by 0.06379 %. Model 7 identifies a non-linear effect of FDI on the ECI, suggesting the presence of non-linear dynamics in this relationship. Taken together, these results highlight the complementary nature of FDI and AC, indicating that regions with stronger absorptive capacity are better equipped to leverage foreign investment to achieve higher levels of economic sophistication.

Our results for FDI, AC, and their interaction terms are consistent with previous evidence (Iwamoto and Nabeshima, 2012; Javorcik et al., 2018; Kannen, 2020), which indicates that FDI enhances regional economic complexity by increasing both ubiquity and diversity. In addition, this study employed lagged values of FDI and AC, following the approaches of Javorcik et al. (2018) and Kannen (2020), to mitigate potential simultaneity problems. Moreover, the findings confirm that AC exerts a favorable and statistically significant effect on ECI, reinforcing the view that local capabilities are essential for transforming productive structures and expanding export baskets. This result aligns with earlier studies (Azam, 2017; Javorcik et al., 2018) that identified R&D employment, human capital, and years of schooling as reliable proxies for AC. Most importantly, the models presented here advance the literature by demonstrating that FDI alone is insufficient to foster economic sophistication; rather, its effectiveness depends on being combined with adequate levels of absorptive capacity, which enables regions to fully benefit from foreign investment and achieve higher levels of economic

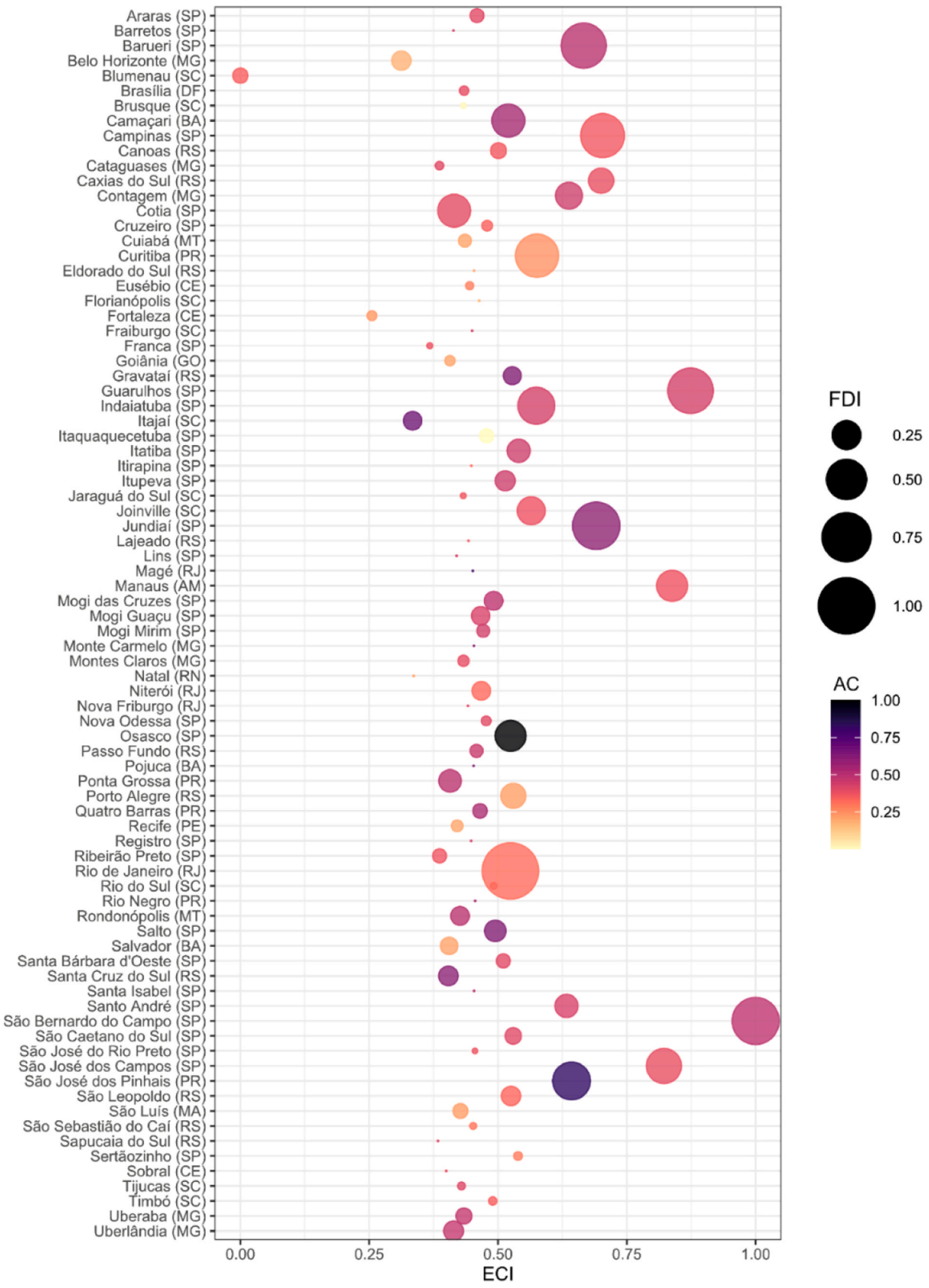

Fig. 1. Bubble plot showing the municipalities' (Y axis) ECI (X axis), FDI (size), and AC (color grade) levels (normalized values, 2014 data).

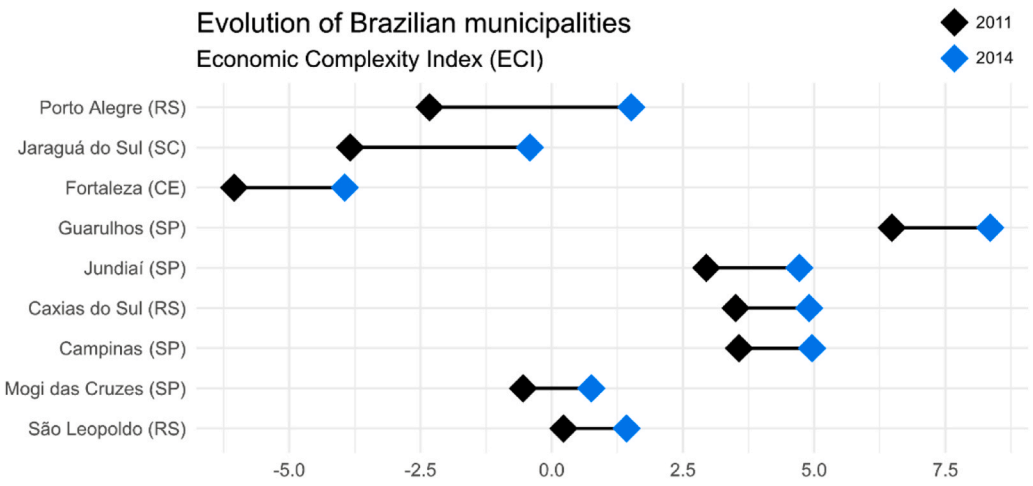

Fig. 2. Evolution of the ECI.

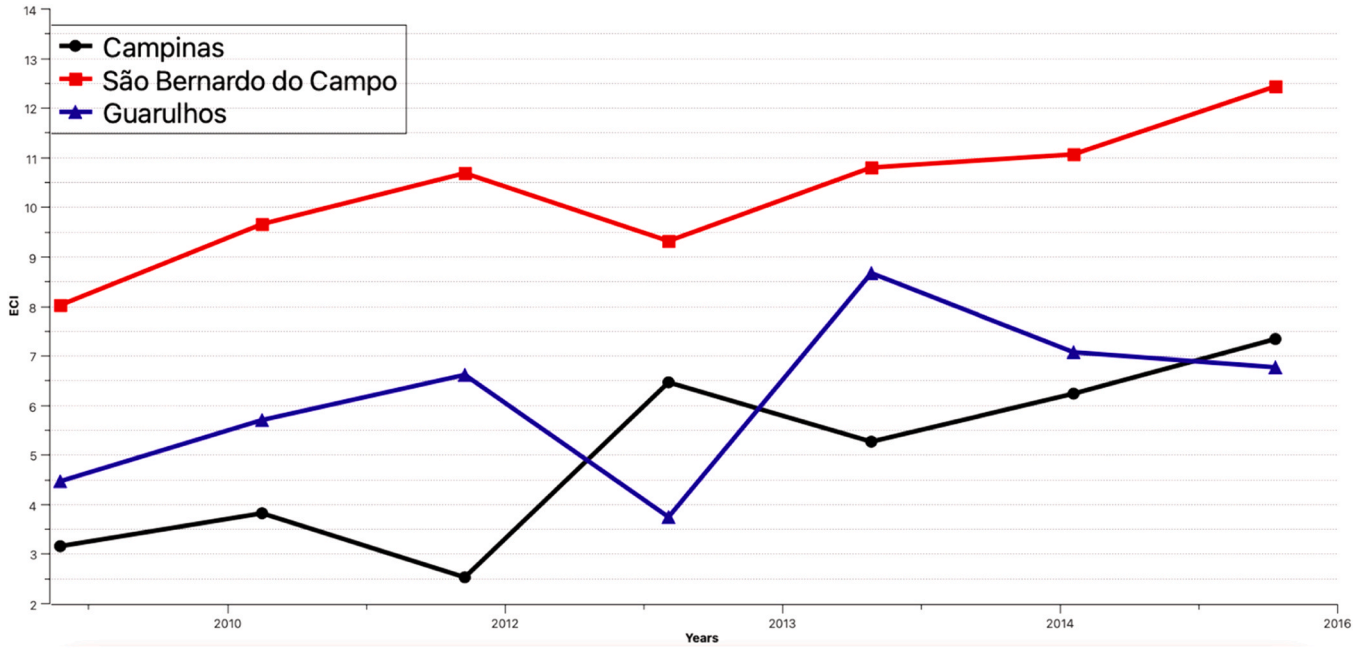

Fig. 3. Productive sophistication in selected Brazilian municipalities.

complexity.

Regarding the control variables, GDP per capita (GDPPC) is positive in all models. Indeed, rich regions can afford more sophisticated products and possess better human capital, which aligns with previous studies (Hartmann, 2018; Hidalgo and Hausmann, 2009). Additionally, Model 1 indicates a positive and statistically significant relationship between population density (DENS), which aligns with the findings of Balland et al. (2020). In other words, complex activities are concentrated in large cities, which have a higher population density (Ahlfeldt and Pietrostefani, 2019). Several factors can explain this, including the attraction of highly qualified professionals by high-wage, high-rent cities. This also explains the positive and significant relation between the number of jobs that require a college education (WQ) and ECI.

Furthermore, the results indicate a negative and statistically significant effect of agriculture on the ECI across all models, which may reflect the substantial reliance of Brazilian municipalities on agricultural production and exports (Xavier et al., 2023). Additionally, the industrial sector exhibits negative and statistically significant coefficients in some models, although their magnitudes are relatively small. This finding contrasts with previous studies, such as Neffke et al. (2011). However, it may be explained by the process of deindustrialization experienced in Brazil over the past two decades, which likely influenced the sign of the estimated coefficient (Oreiro, Manarin, and Gala, 2020; Almeida and Balanco, 2024). Moreover, the industrial sector in this study encompasses a broad range of subsectors, many of which may not significantly contribute to economic complexity.

Additionally, the quantity of college-required works (*WQ*) has a positive and statistically significant relationship with ECI across all models. The development of capabilities, which requires human capital, is one aspect that influences how simple industries evolve into more complex ones. In this situation, education and employment opportunities that require a higher level of education help the region produce more complex goods, thereby increasing the complexity of the regional economy (Hausmann et al., 2013).

The IFGF, which proxies municipal institutional quality, exerts a positive and statistically significant effect on the ECI in several model specifications. This result suggests that municipalities with stronger fiscal management and institutional capacity are better positioned to

Table 1
FDI, AC, and ECI: Linear results and interactions.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDI_{t-1}	0.01294***	0.00007					−0.00354
	(0.00369)	(0.00696)					(0.01071)
$(FDI_{t-1})^2$							0,02143*
							(0.01297)
AC	0.06204***						0.06216***
	(0.01152)						(0.01204)
AC_{t-1}		0.15710***					
		(0.01506)					
$FDI_{t-1} \times AC_{t-1}$			0.05657*				
			(0.02584)				
$FDI \times AC_{t-1}$				0.07666**			
				(0.02945)			
$FDI \times AC$					0.09228***		
					(0.01870)		
$FDI_{t-1} \times AC$						0.06379*	
						(0.04092)	
log (GDPPC)	0.00156**	0.00017	0.00053	0.00069	0.00140**	0.00053	0.00138*
	(0.00052)	(0.00101)	(0.00104)	(0.00103)	(0.00053)	(0.00104)	(0.00054)
DENS	0.00003*	−0.00001	−0.00001	−0.00001	0.00003	−0.00001	0.00001
	(0.00130)	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)	(0.00001)
IND	−0.00027	−0,00084**	−0.00073**	−0.00082**	−0.00038*	−0.00074**	−0.00025
	(0.00018)	(0,00028)	(0.00028	(0.00029)	(0.00019)	(0.00028)	(0.00019)
AGRO	−0.00066*	−0.00134*	−0.00179**	−0.00171**	−0.00085*	−0.00179**	−0.00077*
	(0.00038)	(0.00055)	(0.00055)	(0.00057)	(0.00038	(0.00055)	(0.00038)
WQ	0.80182***	1.04903***	1.03599***	1.02748***	0.86617***	1.03599***	0.80112***
	(0.04733)	(0.13750)	(0.12581)	(0.13580)	(0.08875)	(0.12581)	(0.08893)
IFGF	0.01525	0.02778*	0.05828***	0.05477***	0.02250*	0.05828***	0.01711*
	(0.00956)	(0.01447)	(0.01396)	(0.01405)	(0.00923)	(0.01396)	(0.00975)
Constant	0.12238***	0.12578***	0.13281***	0.13125***	0.12754***	0.13637***	0.12158
	(0.01135)	(0.01873)	(0.01894)	(0.01905)	(0.01151)	(0.01894)	(0.01160)
Observations	939	706	706	706	939	706	939
Number of cities	192	178	178	178	178	178	192

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

leverage resources, implement development strategies, and create an environment that fosters productive diversification. Consequently, institutional quality emerges as an important factor to economic sophistication in Brazil (Acemoglu, 2010; Vu, 2022).

In sum, the results from Table 1 provide strong evidence that both foreign direct investment (FDI) and absorptive capacity (AC) play significant roles in enhancing regional economic complexity, particularly when considered in combination. The presence of potential threshold effects, as indicated by the non-linear specification in Model 7, underscores the need to move beyond linear estimations and adopt non-linear models.

4.3. Non-linear econometric findings

This topic presents the threshold model to analyze the impact of FDI and AC on ECI. Table 2 presents the results of the panel threshold regression, which allows us to test the non-linear impact of foreign direct investment (FDI) on the Economic Complexity Index (ECI), conditional on absorptive capacity (AC).

The model identifies a statistically significant threshold level of AC at 0.658, indicating that municipalities must achieve this minimum capability to capture the positive effects of FDI. Such nonlinear behavior was, to some extent, anticipated by the literature, which highlights threshold effects (Girma, 2005). This finding is particularly relevant in the Brazilian context, where regional heterogeneity implies that not all municipalities are equally prepared to benefit from foreign investment. Our results reveal that below the threshold level, the impact of lagged FDI on ECI is positive but weaker, with an estimated coefficient of 0.048220. In contrast, once municipalities surpass the AC threshold, the effect of FDI on ECI becomes stronger, reaching 0.124500. This evidence highlights the conditional nature of FDI's contribution to economic sophistication: foreign investment alone is insufficient, but when combined with adequate levels of local capabilities, it significantly accelerates the diversification and complexity of regional productive structures.

Table 2
Threshold estimate.

Variables	Threshold
Constant	0.064310*
	(0.029880)
$FDI_{t-1} for (\leq \lambda_1)$	0.048220***
	(0.017640)
$FDI_{t-1} for (> \lambda_1)$	0.124500*
	(0.112100)
GDPPC	0.001816
	(0.002139)
DENS	−0.000019*
	(0.000009)
IND	0.000207
	(0.000237)
AGRO	−0.002074***
	(0.000434)
WQ	1.114000
	(0.082740)
IFGF	0.076450***
	(0.021080)
Threshold (λ_1)	0.658***
	(0.019)
Observations	926
Adjusted R-squared	0.4573
Multiple R-squared	0.4631

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The control variables included in the model provide further insights. Agriculture maintains a statistically significant and negative relationship with ECI, reflecting the structural dependence of many municipalities on agricultural exports. By contrast, institutional quality, as proxied by the Firjan Index of Fiscal Management (IFGF), exhibits a substantial and significant positive effect, confirming that governance

plays a crucial role in enabling regions to absorb and leverage foreign knowledge.

Overall, the threshold regression validates Hypothesis 3, which posits that the benefits of FDI for economic complexity are contingent on surpassing a minimum level of absorptive capacity. These results confirm the non-linear dynamics of the FDI–AC–EC nexus and emphasize the importance of strengthening human capital, technological infrastructure, and institutional quality to ensure that municipalities reach the capability thresholds required to transform foreign investment into productive sophistication.

4.4. Sensitivity tests

Analyzing local data allows us to evaluate a micro-regional phenomenon, despite the difficulty of finding available data. In this sense, a smaller number of observations might affect sample reliability, which requires robustness and sensitivity testing. Hence, we perform a sensitivity test. Our goal is to check whether our sample is reliable and whether outliers are damaging the findings.

For this reason, we have trimmed our sample (2.5 % and 97.5 %) according to the ECI and lagged FDI levels simultaneously. Table 3 demonstrates the robustness of the sample, as the results remain consistent, particularly regarding the isolated effect of AC and its interaction with FDI, both of which exhibit a positive and statistically significant relationship, in line with the general model. It is noteworthy, however, that the trimmed estimation faces difficulties in identifying significance for FDI in isolation in Models 1 and 7. Nevertheless, we argue that the positive and significant results observed in the general model show robustness to the conclusions, although the limited sample size must be considered.

5. Final remarks and political implications

This study advances the understanding of the relationship between Foreign Direct Investment (FDI), absorptive capacity (AC), and economic complexity (EC) in emerging economies, providing novel insights at the municipal level. Our results confirm that FDI has a positive influence on economic complexity only when a minimum threshold of absorptive capacity is present. This finding refines previous theoretical frameworks (Cohen and Levinthal, 1989; Girma, 2005) by empirically validating the conditional and non-linear nature of FDI benefits in a regional context characterized by high heterogeneity.

Moreover, our research contributes to the growing body of literature that emphasizes the pivotal role of local capabilities in mediating the developmental impact of external economic forces (Nguea, 2024; Nguyen and Su, 2021). In line with recent perspectives, we demonstrate that investments alone are insufficient for structural transformation without parallel development in human capital, infrastructure, and innovation systems. By utilizing a unique municipal dataset and applying threshold regression, this study offers a methodological innovation relevant for scholars investigating regional development dynamics in emerging markets.

Our findings have important implications for managers, policymakers, and regional development strategists. First, FDI attraction policies must be accompanied by initiatives that enhance absorptive capacity, including investments in education, technological infrastructure, and local R&D ecosystems. Offering tax incentives or infrastructure improvements to foreign firms alone will not maximize the benefits of FDI if local firms and institutions are unable to absorb and apply new knowledge effectively. Second, sectoral targeting emerges as a crucial strategy. Policymakers should prioritize foreign investments in industries that are either adjacent to existing regional capabilities or have the potential to catalyze the emergence of new, sophisticated sectors. As emphasized by Timbe et al. (2024) and Ascani et al. (2020), encouraging FDI into high-complexity industries can foster more substantial knowledge spillovers and long-term economic resilience. Third, regional innovation systems must be strengthened to facilitate collaboration between multinational enterprises (MNEs) and local actors. This

Table 3
Sensitivity analysis – Trimmed regressions.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDIt−1	−0.002574	0.005826					0.029690
	(0.006825)	(0.009884)					(0.018655)
(FDIt−1) ^{2}							0.056601*
							(0.030376)
AC	0.083648***						0.081647***
	(0.012346)						(0.012105)
ACt−1		0.144847***					
		(0.017729)					
FDIt−1 x ACt−1			0.121357**				
			(0.038745)				
FDI x ACt−1				0.142260**			
				(0.054374)			
FDI x AC					0.057818*		
					(0.034279)		
FDIt−1 x AC						0.153591*	
						(0.06350)5	
log (GDPPC)	−0.001193	0.001708	−0.000536	−0.000653	−0.001216	−0.000476	−0.001229
	(0.000800)	(0.001213)	(0.001367)	(0.001340)	(0.000862)	(0.001372)	(0.000802)
DENS	0.000426	−0.000007	−0.000004	−0.000005	−0.000007	−0.000004	−0.000007
	(0.001167)	(0.000009)	(0.000010)	(0.000011)	(0.000010)	(0.000011)	(0.000010)
IND	−0.000136	−0.000232	−0.000057	−0.000118	−0.000114	−0.000079	−0.000165
	(0.000179)	(0.000224)	(0.000250)	(0.000252)	(0.000186)	(0.000251)	(0.000178)
AGRO	−0.000820*	−0.000799*	−0.001178*	−0.001159*	−0.001077**	−0.001214*	−0.000869*
	(0.000377)	(0.000435)	(0.000481)	(0.000488)	(0.000382)	(0.000485)	(0.000371)
WQ	4.910446***	4.015764***	4.555505***	4.599119***	4.639884***	4.548987***	4.878955
	(0.476065)	(0.481639)	(0.482233)	(0.497840)	(0.464358)	(0.487516)	(0.467002)
IFGF	0.016168	0.012989	0.035949*	0.033127*	0.028229*	0.037218*	0.015849
	(0.012184)	(0.014954)	(0.016303)	(0.016119)	(0.012487)	(0.016390)	(0.012106)
Constant	0.129694***	0.090849***	0.120889***	0.124279***	0.134535***	0.120659***	0.132287***
	0.013853	0.019185	0.021567	0.021257	0.014828	0.021686	0.013843
Observations	869	629	653	653	869	653	869

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

includes fostering partnerships between universities, research centers, and firms (Sultana and Turkina, 2020). Policies aimed at facilitating labor mobility, skill development, and technological entrepreneurship are crucial for fully leveraging the presence of foreign investors. Ultimately, our findings urge policymakers to adopt an integrated development strategy that simultaneously targets the attraction of FDI and capability upgrading to foster inclusive and sustainable economic growth.

While this study provides valuable insights, it also opens several avenues for future research. First, subsequent studies could explore sector-specific analyses to assess whether specific industries exhibit stronger FDI–AC–EC linkages. Disaggregating FDI by sector would allow a more granular understanding of how foreign investments in manufacturing, services, and agriculture contribute to economic sophistication. Second, future research should consider spatial spillover effects by employing spatial econometric models and understanding how FDI and absorptive capacity in one municipality influence neighboring regions would deepen the comprehension of regional development dynamics and potentially reveal externalities that current models do not capture (Balland et al., 2020). Third, comparative cross-country analyses could extend this framework to other emerging economies such as South Africa, India, and Indonesia, where regional disparities are also pronounced. Applying similar methodologies across different national contexts would enhance the generalizability of the findings and offer valuable policy lessons for global development strategies. Fourth, scholars could further investigate the role of digital infrastructure and ICT development as part of absorptive capacity, particularly given the increasing importance of technological readiness in driving economic complexity. Fifth, we recommend that future studies replicate this analysis in other emerging countries, covering additional regions, and further investigate the role of FDI and AC on economic complexity. Sixth, it is also important to acknowledge that one limitation of this study lies in the relatively short period analyzed, which may not fully capture more profound structural transformations within the productive system. Nevertheless, this does not compromise the validity or relevance of the results obtained, as the analysis still provides robust evidence of the mechanisms at play.

To conclude, this study demonstrates that the relationship between FDI, AC, and economic complexity in Brazilian municipalities is both conditional and non-linear. While FDI can play a pivotal role in fostering productive sophistication, its benefits only materialize when regions possess sufficient levels of AC, underscoring the importance of local capabilities as a prerequisite for structural transformation. By introducing novel municipal-level data and applying robust econometric methods, this research advances theoretical, methodological, and policy debates on the determinants of economic complexity in developing contexts. Ultimately, the findings highlight that policies aiming to attract FDI must be accompanied by strategic investments in human capital, innovation systems, and institutional quality, ensuring that municipalities not only receive foreign capital but also have the capacity to translate it into long-term developmental gains.

Ethical statement

This article does not use animal or human subjects. For this reason, there is no Ethical Statement needed.

CRediT authorship contribution statement

Daisy Aparecida do Nascimento Rebelatto: Writing – review & editing, Supervision. **Eduardo Polloni-Silva:** Visualization, Investigation, Data curation. **Ana Catarina Gandra de Carvalho:** Writing – original draft, Visualization, Investigation, Data curation. **Herick Fernando Moralles:** Writing – review & editing, Methodology. **Gregory Matheus Pereira de Moraes:** Writing – original draft, Validation, Methodology. **Diogo Ferraz:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Declaration of Competing Interest

The authors declare that there is no conflict of interest to disclose. The views expressed are those of the authors and not those of their respective institutions.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.joitmc.2025.100657.

Data availability

The database will be available upon request. Moreover, all the data is available in open databases (i.e., World Bank).

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