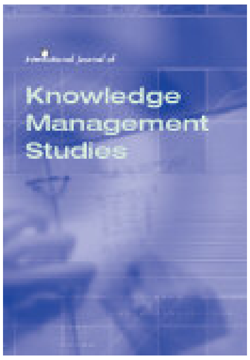

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Knowledge production and innovation: the potential of local universities to create technology-based companies in the Brazilian State of Minas Gerais

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Knowledge production and innovation: the potential of local universities to create technology-based companies in the Brazilian State of Minas Gerais

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Abstract: This paper analyses the effects of the human capital (university researchers and graduate students) and the knowledge assets (academic publications, academic patent petitions and postgrad scholarship numbers) of the universities of Minas Gerais State, Brazil, on the creation of technology-based companies (TBCs) in its 12 mesoregions. Based on the InovaData-MG TBC census and open government data from the years 2000 to 2017, this study seeks to outline a knowledge production function for the Minas Gerais ecosystem and explore possible divergences in the innovation potential of its mesoregions. The negative binomial regression model was used to test hypotheses using variables from the state's mesoregions that quantify the human capital characteristics that generate research and its knowledge assets to assess their influence on the new TBC creation. The data analysis methodology has an explanatory and predictive character which made it possible to verify part of the proposed empirical model's validity. The results of this work confirm that human capital of universities and region maturity positively influences the average propensity to create new TBC.

Keywords: knowledge management; regional knowledge; innovation; technology-based companies; TBCs.

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1 Contextualisation and proposal

The concept of regional knowledge (RK) refers to territorial units, which are part of a national state, and operate as innovation ecosystems following the new logic of the knowledge economy and society (Asheim and Isaksen, 2002; Etzkowitz, 2014; Fritsch and Mueller, 2007; Fritsch and Wyrwich, 2018; Huggins and Thompson, 2015; Lepik and Krigul, 2016; Modrego et al., 2015). In the last two decades, the application of knowledge concepts to geographic regions seeks to clarify the relationships among knowledge, learning, innovation, regional economic development and spaces connected to them (Audretsch et al., 2012; Fritsch and Wyrwich, 2018; Gonçalves and Fajardo, 2011; Gunnarsson and Wallin, 2011; Heblich and Slavtchev, 2014; Huggins and Thompson, 2015; Hülsbeck and Pickavé, 2014).

Collaboration and sharing are vital elements of knowledge management and production and have an impact on the innovative potential of emerging science-oriented regions. The contemporary global competition process highlights knowledge's 'ability to perform' (Guile and Visockis, 2008), that is, its instrumental capability to solve everyday problems and create innovative solutions. Thus, the knowledge produced is required to be economically useful and play not only a vital role in economic growth, but also in the social development of a geographic region (OECD, 1997).

The rate at which disruptive innovations are generated is changing the criteria which make regions attractive for production and investment. Global value chains remain concentrated in a relatively small number of locations and tend to focus on the source of knowledge (WEF, 2018). However, as the capabilities for absorption, assimilation, connection, and creation of new opportunities are different in each location, the impacts of such journey are also plural. It is admitted that benefiting from the new knowledge economy will only be possible for those who specialise in knowledge-intensive activities (Armstrong et al., 2009; Cherubini Alves et al., 2018; Hipp, 1999) or possibly those who connect to a strong collaborative network.

Universities have increasingly been viewed as a support structure for innovation, providing trained professionals, research results, useful knowledge to industry, in addition to their involvement in the formation of firms through incubator facilities based on technology originating from academic research (Etzkowitz, 2003a). A university in which research results are routinely scrutinised for commercial as well as scientific potential is becoming the modal academic institution, which has the internal capabilities to translate research results into intellectual property and economic activity according to a predictable metric (Etzkowitz, 2003b). Universities, in addition to fulfilling educational and research functions, increasingly undertake an entrepreneurial role, creating small innovative companies and becoming thus a stakeholder in socio-economic development (Ivanova, 2014).

From the perspective of 'capitalisation of knowledge' (Etzkowitz, 2003b), entrepreneurship and innovation must be linked to science, technology and innovation, and therefore, with universities. In recent years, Brazil has emerged as a generator of scientific knowledge, with 2.05% of articles published in scientific journals indexed in the Scopus database, occupying, in 2016, the 14th position (Scimago Journal & Country Rank, 2021). Public universities are mainly responsible for this scientific and technological research, and, unfortunately, this knowledge is modestly reflected in technological innovation (Matos et al., 2019). According to MSTI (2016), only 0.55% of patents via the Patent Cooperation Treaty (PCT) are deposited by Brazilian researchers. Currently, the country occupies the 69th position in the world ranking of innovation, while in 2012 it was in the 42nd position.

Similarly, given the correlation between technology, innovation and economic development, the country collapsed in the competitiveness ranking. In 2012, the World Economic Forum (WEF) investigated the competitiveness of 144 nations, considering three groups: basic requirements, efficiency enhancers and innovation and sophistication factors. The Brazilian performance in each of these indexes was the 73rd, 38th and 39th position, respectively. The country also ranked 48th in the 2012 world competitiveness ranking (WEF, 2012). In 2017, the Brazilian performance decreases in each of these indexes and was the 104th, 60th and 65th position, respectively, which took Brazil to 80th position in the 2017 world competitiveness ranking (WEF, 2017b).

Despite the deficiencies and criticisms of these rankings, it is clear that the country is far from its possibilities, and the technological development achieved is not up to the potential scientific knowledge, as also observed in Bagno et al. (2020). Additionally, it is known that the characteristics of innovative processes in developing countries are significantly different from those of most developed economies (Gonçalves et al., 2018). Those differences are also registered in the growth of technology-based companies (TBCs) (Marquis and Raynard, 2015). Relations between academic institutions and companies are also still very fragile, hindering the consolidation of the innovation process and, consequently, the intended economic and social development.

Bogers et al. (2019) defends that while the technological innovation process has been increasingly adopted in developed countries, firms from emerging markets, such as Brazil, markedly fall behind this trend and needs to be understood. Additionally, Gonzaga et al. (2020) affirms that studies on Brazilian start-ups are still relatively scarce and not conclusive. They addressed the interaction with the start-up ecosystem in Northeast of Brazil and found that higher start-up development stages are positively associated with higher levels of organisational learning capacity. Teixeira et al. (2021) studied the growth of 137 Brazilian start-ups and found indications that technological and networking capacities are not a determinant of growth. Escalfoni et al. (2020) work contributes to the broadening of knowledge about the importance of the partnership network to boost the nascent business. These findings are still inconclusive and underline the need of further studies on the drivers for the growth of TBCs.

The paucity of information on the role universities play in the compilation and application of innovative knowledge in developing regions, as well as the contribution of such institutions to the creation of TBCs, constitute an important theoretical gap. So, the present work seeks to contribute in this respect through a study of the effects of human capital and the knowledge assets of the regional universities of Minas Gerais State (MG) on the creation of TBCs in the state mesoregions.

The Brazilian State of Minas Gerais has been chosen for the present study since it was, in 2017, home to almost 1,000 TBCs focused on innovation, distributed in four technology parks, 21 business incubators, 13 accelerators, 31 communities and several coworking spaces and other innovation environments (InovaData-MG Platform, 2018). The MG has, approximately, 21 million inhabitants in 2020, the third largest economy in Brazil, with a share of approximately 8.7% in the Brazilian gross domestic product (GDP), only behind the States of São Paulo and Rio de Janeiro, which account for 32.4% and 11%, respectively of the national (GDP). With a diverse economy, the state service sector is more dynamic than the other sectors. The structure of public and private universities of MG, with enrolments of more than 550,000 in higher education, is a reference in Brazil.

To assess this potential for generating innovative knowledge, the TBC data available by InovaData-MG Platform is used. The performance of universities in MG regions was measured using variables collected from open data platforms of the state government, related to the activities of universities over 17 years. The research question, therefore, is to assess the impact of human capital (university researchers and post graduate students) and knowledge assets (academic publications, academic patent petitions and postgrad scholarship numbers) of universities of MG on the emergence of new TBC in different state regions. What is the role of the universities (human capital and the knowledge assets) in the mesoregions of Minas Gerais in the creation of new TBC?

The present article is organised into four sections. The following section presents literature data on knowledge drivers; subsequently, there is the development of hypotheses to be tested concerning the performance of universities in the regions. Section 3 presents the data and the methodological approach used in the present study, followed by a discussion of the results. The conclusions and implications summarise the impacts of the main findings.

2 Literature review and hypothesis construction

2.1 Knowledge production capabilities in the region

Studies suggest that the level of technological sophistication of new ventures is influenced by regional factors. Such studies indicate that the intensity of research and the directives for technology transfer adopted by the universities predict the occurrence of high-tech start-ups (and spin-offs) (Audretsch et al., 2012; Hülsbeck and Pickavé, 2014). This shows that basic research and technology transfer efforts by universities urge special attention to promote increments in regional development.

Exploratory models of the role of knowledge production also link investments in R&D with the generation of patents (Nicola et al., 2018; Perret and De, 2017; Wei, 2012), with productivity growth (Coccia, 2009; Zimmermann, 1995), and justify that they can be considered important drivers for the innovative performance of a region (Barrutia et al., 2014; Rothaermel and Ku, 2008). Researchers seek to quantify the reasons for regional differences in start-ups rates (Fritsch and Wyrwich, 2018; Hülsbeck and Pickavé, 2014; Kassicieh, 2010; Leyden and Link, 2013), showing that regions with high innovation activity through production patents have greater innovation efficiency (Kalapouti et al., 2017).

An ecosystem of knowledge and innovation provides the foundation for regional growth in the form of a 'critical mass', a concentration of research resources on a given topic, from which technological ideas can be generated (Audretsch et al., 2012; Etzkowitz, 2008). When these resources reach a certain level, they can play a role in regional development (Etzkowitz, 2008). It is from such knowledge 'spaces' of consensus and innovation that, according to Etzkowitz (2008), the concept of the regional Triple Helix model for innovation emerges.

The three main functionalities of the Triple Helix, according to Leydesdorff and Ivanova (2016) are

1 the production of knowledge (performed mainly by the academy)

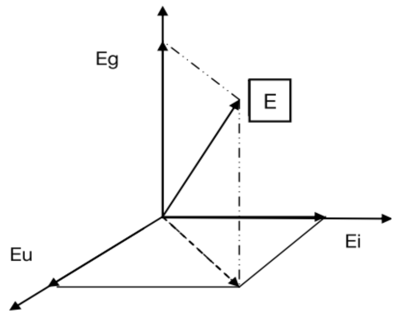
2 the generation of wealth (industry)

3 normative control (governance).

Once they have analytically independent sources of variation, they can be represented as orthogonal axes of a Cartesian coordinate system, as shown in Figure 1.

Figure 1 represents the degree to which propellers promote innovative knowledge. The function resulting from the three coordinated axes would be energy (E), strength, or intensity of this production of innovative knowledge resulting from the interactions of the ecosystem. Thus, the variable E represents the total intensity of the resulting field, and E_u, E_i and E_g, respectively, symbolise the intensity of performance by the university, industry, and government; then $E = f(E_u, E_i \text{ and } E_g)$ is the result of the interaction. The resulting E function, which measures the intensity of innovation-producing knowledge activities, has been assessed in some regions through the number of TBC created in the ecosystem (Aldrich and Yang, 2014; Audretsch and Keilbach, 2004; Heblich and Slavtchev, 2014; Horaguchi, 2016; Motohashi, 2005). In the Triple Helix model, the university (vector E_u, in Figure 1) stimulates the development of new companies based on research, introducing 'knowledge capitalisation' as an academic goal (Etzkowitz, 2008).

Figure 1 Triple Helix as a function in a Cartesian coordinate system



Source: Leydesdorff and Ivanova (2016)

The direct involvement of science (universities) with the business world (industry) has increased in recent years along with government policies aimed at promoting knowledge transfer, and finding effective applicability for research (Teixeira and Mota, 2012). In a longitudinal analysis study of the connection between Chinese universities, and industrial companies, Wang et al. (2013) measured aspects such as patent licensing, co-patents and co-authorship, with the objective of examining the ways in which industries access university-produced knowledge, and the impact of such innovation outlets. In such study, a positive effect of the university-industry collaborations was observed in subsequent results of the companies' innovation.

Studies on the issues mentioned above in developing countries are more scarce and less conclusive (Freitas et al., 2013; Ranga et al., 2003; Wang et al., 2013). Specifically in Brazil, where this theme is emerging, there is a consensus regarding the low connection between companies and universities and, when it exists, it is how this relationship happens that affects the generation of knowledge-intensive spin-offs (Brandão Fischer et al., 2018; Cherubini Alves et al., 2018).

According to the MG Startups Census (Faria et al., 2017), Belo Horizonte, the capital of MG, appears in the list of cities with the highest number of start-ups in Brazil (3rd position, according to a survey by the Brazilian Association of start-ups in partnership with Accenture). The Metropolitan Region of Belo Horizonte (RMBH) concentrates the largest number of start-ups in the state of MG (41%), followed by southern MG (17%). According to this same study, the number of start-ups in MG has grown by 320% from 2015 and by 556% from 2010 to 2017. It is estimated that, currently, there are about 1.050 start-ups in the state. Of these, 521 responded to the census conducted by the study.

The spatial concentration of companies, public research centres, universities and qualified human capital combined with the need for investments in research are also factors that contribute to the concentration of innovative activity in certain urban centres and their surroundings (Audretsch et al., 2012; Audretsch and Keilbach, 2004; Barrutia et al., 2014; Cherubini Alves et al., 2018; Faria et al., 2018; Fritsch and Franke, 2004; Fritsch et al., 2011; Goldschlag et al., 2016; Gonçalves et al., 2018; Horaguchi, 2016; Hülsbeck and Pickavé, 2014; Márquez and Velasco, 2018). This hypothesis is particularly valid for MG, a state of the Brazilian federation that stands out as an important innovative region and with the largest number of federal public universities in the country, which are 11 in a total of 55 (Chiarini et al., 2012).

2.2 Universities driving knowledge and innovation

Economic growth, according to Romer (1986), is related to new knowledge embedded in human capital. In this way, the new knowledge is created by an interactive learning process, in which innovation (Arrow, 1962) and education (Uzawa, 1965) would play a crucial role. Machlup (1962) distinguished productivity in education (or performance) from education productivity (or simply productivity) by measuring its contribution to the economy (in terms of accounting). The model of Griliches (1979) and Jaffe et al. (1993) subsequently presented a regional function of knowledge production as a combination of industrial R&D and university research, estimating the combined production of innovative activities carried out by industrial and university institutions (Hülsbeck and Pickavé, 2014; Modrego et al., 2015).

Knowledge production through academic research, as one of the main businesses in universities, is of crucial importance to economic and social development (Hülsbeck and Pickavé, 2014). Several studies have found a significant relationship between investments in R&D and a region's innovative capabilities (Leydesdorff and Ivanova, 2016; Lopez-Rodriguez and Martinez-Lopez, 2017; Wei, 2012). Thus, both the production of knowledge and technological innovation/economic development of a region demand an active role by universities (Osinski et al., 2018).

The university is an especially propitious site for innovation due to such basic features like its high rate of flow through of human capital in the form of students who are a source of potential inventors (Etzkowitz, 2003b). The university is a natural incubator, with flexible resources, people a good deal of whose time is potentially flexible, with access to inexpensive human resources, students, who can be organised to undertake new projects (Etzkowitz, 2003a). The university's unique comparative advantage is that it combines continuity with change, organisational and research memory with new persons and new ideas, through the passage of student generations (Etzkowitz and Leydesdorff, 2000).

The Triple Helix thesis states that the university can play an enhanced role in innovation in increasingly knowledge-based societies (Etzkowitz and Leydesdorff, 2000). To be an entrepreneur, a university has to have a considerable degree of independence from the state and industry, but also a high degree of interaction with these institutional spheres (Etzkowitz, 2003a). A Brazilian study (Thomas et al., 2021) analyses the role of universities as orchestrators of the development of a regional ecosystem that is conducive to innovation and entrepreneurship. Results demonstrated, reinforcing major findings, that universities perform several orchestration processes, such as fostering knowledge mobility, managing innovation, and increasing network stability. However, such orchestration processes emerge when universities take on leadership positions in the region.

The linear model, either expressed in terms of 'market pull' or 'technology push', was insufficient to induce transfer of knowledge and technology. Publication and patenting assume different systems of reference both from each other and with reference to the transformation of knowledge and technology into marketable products (Etzkowitz and Leydesdorff, 2000). The transfer of technology has been accepted as an administrative function of research universities even as publication of research was earlier accepted as a responsibility of faculty members (Etzkowitz, 2003b).

2.2.1 Innovation potential measure

The TBCs created in MG were analysed in this study to assess the innovative potential of the region and its relations with human capital, research, investment, and knowledge characteristics of the locality. A TBC, according to the definition of the study conducted by the Management Technology Center (MTC) of the Federal University of Viçosa (UFV) "is one whose competitive strategy is to offer products and services, or establish processes, with high added value, based on scientific and technological knowledge and on the use of techniques and methods considered innovative" [Faria et al., (2017), p.11]. In the context of TBC, the study applies the approach used by Faria et al. (2017), which includes incubated, graduated and resident companies of products or services.

Incubated companies are new TBCs linked to pre-incubation, incubation and acceleration programs or even other modalities of supporting programs. Graduated companies are those who have completed participation in incubation programs and are, therefore, at a more advanced evolution stage. Resident companies are those which have established themselves in technology parks, whether or not they have undergone incubation programs (Faria et al., 2017).

TBC, then, include start-ups, spin-offs and, also, companies that are already in more mature evolution stages, but have emerged and maintain themselves due to the knowledge generated in their creation. Therefore, this group of companies represents the pull value created through innovative knowledge that has some form of technology in its creative base. Therefore, the present study argues that the growth in the number of TBC represents the growth in the region's knowledge production potential and, therefore, its talent for innovation.

2.2.2 Human capital: university professors and students

The universities' human capital, represented by the academic population of professors and students, is directly related to the capabilities and potential for attracting, organising, and using the knowledge produced in a given region. The proportion of the number of students per professor indicates how much these professors are engaged in teaching and/or in researching. Thus, an increase in the number of students per professors would reduce the ability to conduct research (Audretsch et al., 2012), as they would be focused on teaching. A study developed in Japan, based on multiple negative binomial regressions to confirm the interdependence of the Triple Helix variables, showed that the increase in the number of university researchers promoted the establishment of new start-ups in a regional context (Horaguchi, 2016). Evidence from MIT case (O'Shea et al., 2007) also suggests that the quality of research university staff is one attributes in supporting spin-offs and recommend that it deserve to be studied in more depth. The university research contribution in the creation of TBCs is an important factor to be better explored, especially in Brazil where the scientific knowledge has recently increased.

In one of the few Latin American studies that analyse geographic patterns and the relationship between innovation and entrepreneurship at the spatial disaggregation level, the creation of innovations was related to the stock of researchers and entrepreneurs in a regional economy (Modrego et al., 2015). This study, carried out in Chile, measured the number of innovations in the regional economy in each period of time as a growing function of the research stock and regional entrepreneurial skills.

Regional factors that influence the formation of new firms also differ in relation to the technology level of the new venture. This unevenness indicates that the research intensity and technology transfer orientation of universities interfere in the occurrence of high-tech TBSs (in this case, spin-offs) (Audretsch et al., 2012; Hülsbeck and Pickavé, 2014). This indicates that basic research and technology transfer efforts by universities need special attention for increments in regional development. The availability of this 'critical mass' of research in a local area is considered a necessary, but not sufficient, condition for science-based regional economic development (Audretsch et al., 2012; Etzkowitz, 2008).

Additionally, a study conducted by Kassicieh (2010) indicates that large population sizes lead to an economic climate that is important for technology start-ups. Kalapouti et al. (2015) also consider population size in his knowledge production function (KPF) that studied European regions for a 12 years' period to investigate the impact of intra-regional and interregional knowledge spillovers on regional new knowledge production. Although it is believed that the number of university researchers increases with population size, Gao and Guan (2009) observed a strong nonlinear relationship between GDP and population. On the other hand, according to World Bank data, Chinese GDP is growing more than 2,200 times as fast as the population, around 90 times in 40 years since 1970 (https://www.worldbank.org/en/country/china/overview#1). Therefore, the study defends that the number of university researchers increase with population, and both are positively related to the region TBC numbers.

Thus, based on the above argument, this study explores that the number of researchers at local universities is positively related to the creation of TBC in the region.

Hypothesis 1 The number of university researchers in the region is positively related to the TBC number and, hence, population size.

Similarly, it is argued that the number of graduate students as a proportion of the population indicates the potential for human capital formation in the short-term (Audretsch et al., 2012; Baptista and Mendonça, 2010; Cherubini Alves et al., 2018; Horaguchi, 2016), which oxygenates the region's ecosystem. Especially in Brazil, postgrad students are important players in university researches.

Therefore, this study investigates if the increase in number of postgrad students is positively related to the potential increase in the number of TBC in the region.

Hypothesis 2 The number of postgraduate students in the region is positively related to the TBC number.

2.2.3 Knowledge assets: academic publication numbers

Studies show that the main source of tacit knowledge is university research (Acs et al., 2009; Jaffe et al., 1993) as a producer of human capital, and knowledge which 'spills over' (Arrow, 1962) toward regional industries, especially the innovative ones. Academic publications result from intense personal interaction (tacit knowledge) between participants in a research project. Thus, research performance indicators, such as publication numbers or citation figures are commonly accepted and widely used (Agrawal, 2001; Audretsch et al., 2012; Hülsbeck and Pickavé, 2014). Hülsbeck and Pickavé (2014) further argue that post-graduate programs also increase knowledge production.

It was also found, from Brazilian data, that academic publication numbers grow with external funding and with the percentage of professors who hold doctorate degrees, while citations numbers are associated with the existence of post-graduate programs and the recognition of their higher quality (Faria et al., 2018). Accordingly, it is hypothesised that:

Hypothesis 3 The academic publication numbers in the region are positively related to the TBC numbers.

2.2.4 Knowledge assets: academic patent number

From the knowledge production system perspective, academic patents are considered a significant indicator (Hülsbeck and Pickavé, 2014). According to some KPFs, patents should be seen as intermediate outputs, motivating the use of alternative metrics that are closer to commercial results, such as market innovations (Fritsch and Franke, 2004; Hülsbeck and Pickavé, 2014; Modrego et al., 2015). Conversely, others argue that commercially relevant innovation indicators would be the net addition of economically valuable knowledge and not necessarily patents, reinforcing the need for more conclusive studies. These would be a useful measure for empirical analysis on disaggregated scales, comparatively correlated to R&D inputs (Acs et al., 2009; Modrego et al., 2015). Kalapouti et al. (2017) measured, through a structural equations model, the ability to leverage innovative inputs by controlling the regional impact of patent applications, the level of development and the degree of diversity of innovative activity. Nevertheless, an opposing view argues that patents are the result of the knowledge created for basic research and not for profit (Brännback, 2003).

Hence, it is expected that:

Hypothesis 4 The number of academic patent petitions of the region is positively related to the TBC number.

2.2.5 Funding: university research scholarship number

The number of research grants obtained by universities represents the amount of research and development (R&D) capital being injected into the universities' human capital. There are several studies on the relationship among R&D activities and knowledge and innovation production (Audretsch and Keilbach, 2004; Fritsch et al., 2011; Márquez and Velasco, 2018). One of the most well-known KPFs, proposed by Griliches (1979), describes the knowledge generation process as a neoclassical production function, where innovation is a result of R&D inputs that characterise the regional innovation systems and its agents.

A region's effort to develop a stable human capital base is related to the investment level in research, development and innovation (R&D&I) as a percentage of the active population (WEF, 2017a). Therefore, as argued in the present study, the investment in post-graduate scholarships represents accreditation in human capital for promotion of knowledge creation, since the initial stage of a space of local or RK consists in the concentration of R&D activities (Hülsbeck and Pickavé, 2014). Hence, it is hypothesised that:

Hypothesis 5 The numbers of postgrad scholarships in the region are positively related to the TBC numbers.

3 Research methods and procedures

The present study is of a confirmatory nature, since it intends to test hypotheses of dependence, independence and interdependence between variables (facts, data and represented phenomena). In fact, it elaborates a provisional solution (Marconi and Lakatos, 2000) for the following problem: What is the role of the universities (human capital and the knowledge assets) in the mesoregions of Minas Gerais in the creation of new TBC? There is also an explanatory or predictive character in this study, as it seeks logical consistency (internal coherence), compatibility with scientific knowledge (external coherence) and empirical verifiability of the hypotheses.

In this research, the selection of the statistical verification method was based on the fact that the model response variable, or independent variable, is the emergence count of TBC as the measurement for the tangible knowledge production of a region. The independent variable assumes only subtle random values adapted to the Poisson distribution since a normal regression model would be adequate only when the response is continuous.

Various studies applied the Poisson distribution to measure the effects of:

a academic innovation (Fini et al., 2011; Fritsch and Franke, 2004; Hagedoorn et al., 2018; Horaguchi, 2016; Lin, 2017; O'Shea et al., 2005; Rothaermel and Ku, 2008; Silverberg and Verspagen, 2007)

b collaborative experiences between universities and companies (Bruneel et al., 2010; Motohashi, 2005)

c impact of regional competitiveness on innovative activity (Audretsch et al., 2012)

d interdependence of Triple Helix variables in the creation of start-ups (Horaguchi, 2016)

e creation of regional innovation models (Baptista and Mendonça, 2010; Modrego et al., 2015; Tavassoli and Carbonara, 2014).

Given the evidence of over dispersion in the count data, the negative binomial regression model (an alternative model to Poisson regression) is used to model data counts and contingency tables. The main objective is to analyse the relationships between variables, especially how one or more (explanatory) variables, measured on individuals or objects, have on an interest or response variable. Thus, it assumes a response variable Y as a Poisson distribution and its expected logarithm value can be modelled by a linear combination of unknown parameters (Cameron, 1998). Negative binomial regression models are generalised linear models with the logarithm as the link function (canonical) and negative binomial distribution function (Hilbe, 2012).

3.1 Measures and empirical model

The number of new TBC created from 2000 to 2017, obtained from the InovaData-MG database, represent the predictive variable of the model. The explanatory variables are shown in Table 1, as already discussed in the previous section. The data structure is a space-time structure once the TBC by region studied is over time. Longitudinal data for all variables were collect over 17 years and by each of 12 Minas Gerais mesoregions.

Table 1 Explained variables of the theoretical model

VAR	*Variable description*	*Data source*	*References in literature (studies that used the variable)*
X_{u1}	Number of university researchers	CAPES	Akhmat et al. (2014), Audretsch et al. (2012) and O'Shea et al. (2005)
X_{u2}	Number of postgrad students	CAPES	Audretsch et al. (2012), Barrutia et al. (2014), Faria et al. (2018) and Hülsbeck and Pickavé (2014)
X_{u2}	Number of academic publications	Scopus database	Audretsch et al. (2012), Hülsbeck and Pickavé (2014) and Ranga et al. (2003)
X_{u3}	Number of academic patents required	INPI	Akhmat et al. (2014), Audretsch et al. (2012), Cherubini Alves et al. (2018) and Horaguchi (2016)
X_{u5}	Number of postgrad scholarships	CAPES	
DUMMY	Population size	IBGE	Fritsch et al. (2011), Gao and Guan (2009), Kalapouti et al. (2015) and Rothaermel and Ku (2008)
DUMMY	RGDP	IBGE	Arocena and Sutz (2001) and Kalapouti et al. (2017, 2015)
Y	Number of TBCs	Inova Data-MG	Audretsch and Keilbach (2004), Audretsch et al. (2012), Faria et al. (2017, 2018), Horaguchi (2016), Hülsbeck and Pickavé (2014) and O'Shea et al. (2005)

The sample data reconciliation of TBCs, taken from the InovaData-MG Census database from 2019, considered those that responded to the census as active, downloaded, unfit, formally inactive, informally inactive and suspended from incubation programs or from technology parks. This includes, besides the incubated companies, those that have gone through this process, the graduated and the resident ones. The latter are those in a more mature stage of evolution, but which have emerged and are still maintained due to the basic knowledge generated in their creation. This reconciliation premise eliminates part of startups or spin-offs not linked to the incubation program or technology parks, whose representation reaches almost a quarter of them. Therefore, this spectrum of companies significantly represents the pull value created through innovative knowledge that has some form of technology in its creative base. This TBC data is compiled by the 12 MG mesoregions over the researched period.

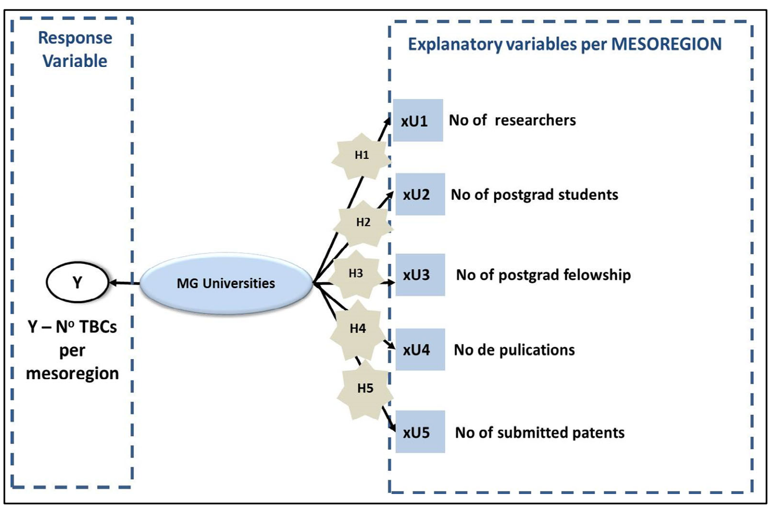
The open data compiled for the independent variables were obtained from the websites of the Coordination for the Improvement of Higher Education Personnel (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES) and the National Institute of Industrial Property (Instituto Nacional de Propriedade Industrial – INPI), using routines built in R language (R Core Team, 2020) and treated so that they can be standardised and summarised on the same basis as the EBT census. Using this information, the study seeks to confirm the formulated hypotheses (Table 2) using the explanatory variables in the negative binomial regression estimation.

Table 2 Hypothesis of the theoretical model

Hypothesis (H1)	The numbers of university researchers in the region are positively related to the TBC numbers.
Hypothesis (H2)	The numbers of postgraduate students in the region are positively related to the TBC numbers.
Hypothesis (H3)	The academic publications numbers in the region are positively related to the TBC numbers.
Hypothesis (H4)	The numbers of academic patent petitions in the region are positively related to the TBC numbers.
Hypothesis (H5)	The numbers of postgrad scholarships in the region are positively related to the TBC numbers.

The proposed conceptual model is based on the influence of the variables considered in the prediction of the number of the new TBC created, as shown in Figure 2. In this illustration, the research hypotheses described in Figure 2, and presented in the previous section, are highlighted. The variables population size and RGDP were used as proxy.

Figure 2 Framework of the proposed theoretical model (see online version for colours)



3.2 Procedures and estimations

The negative binomial regression expresses the probability that a series of events (new TBC creation) will occur considering the usual over dispersion effect in count data. For this reason, Poisson regression was replaced by the negative binomial regression. The linear predictor of the distribution is the linear combination between covariates and the coefficients, which relate to the logarithm of the mean (Venables and Ripley, 2013; Cameron, 1998), as in equation (1).

$$Y_i \sim Negative\ binomial\left(\mu_i, \theta\right), \qquad (1)$$
$$\log_e\left(\mu_i\right) = \eta_i = \beta_o + \beta_1 \times X_1 + \ldots + \beta_q \times X_q, \text{ for } i = 1, \ldots, n,$$

where μ_i is the mean of the i^{th} individual or the year related to the linear predictor η_i. The β is parameters associated with the explanatory variables can be estimated using the maximum likelihood method.

Equation (2) establishes the relationships between the variables under study. The measurement instrument (observed explanatory variables) and the theoretical construct understudy, represented by the predictor variable, are established by the dependent (predictor) and independent (explanatory) relationships.

$$\begin{aligned} Y_i &= f(university, errors), \\ \log_e(\mu_i) &= \eta_i = \beta_o + \beta_1 \times X_{U1} + \ldots + \beta_q \times X_{Uq} + \varepsilon_i, \end{aligned} \tag{2}$$

where μ_i is the estimated or predicted average number of new TBC to be created in the region. $\beta_1, \ldots, \beta_q$ are the estimated parameters for each explanatory variable (X_{Ui}) related to universities performance, and ε_i represents the respective error for each observation. The average generation of regional innovation is then estimated by the linear predictor, which measures the TBC average number in a given year in the region. Therefore, the average TBC for each increment in one of the independent variables X_{Ui} is multiplied by the exponential of the parameter $\hat{\beta}_{Ui}$, considering all other constant factors.

3.3 Adjustment assessments, assumptions and validations

The software R (version 3.6.1) (R Core Team, 2020), which provides users with an open code, was used to adjust the model. The function 'glm.nb' (generalised linear models) is mainly used to calibrate generalised linear models, specified by providing a symbolic description of the linear predictor and a description of the error distribution (Hilbe, 2012).

The selection and validation model phases aim to find sub-models with an average number of parameters that are still adequate to the data, in order to detect discrepancies between the data and the predicted values. Therefore, the independence of observations, data count, non-zero sample covariance, absence of multicollinearity and absence of outliers are assumed (Hilbe, 2012). Three factors are also considered: suitability, parsimony and interpretation. A good model maintains the balance between these three factors.

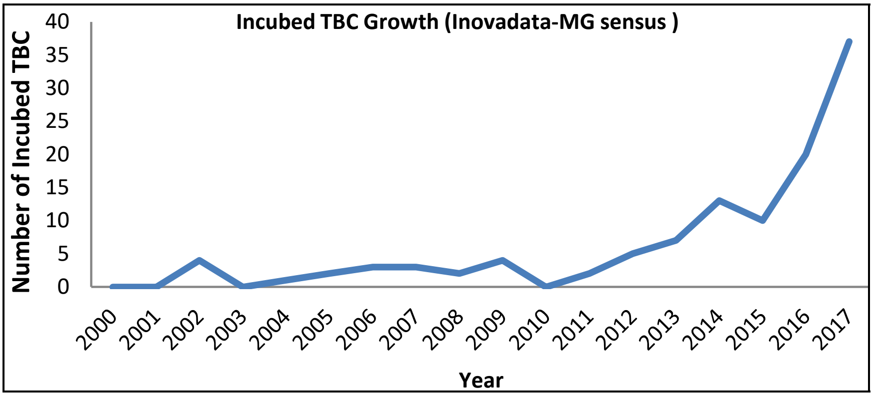
The pseudo-R^2 measure was applied to assess the negative binomial regression model's adequacy and is interpreted as the relative reduction in deviance due to the addition to the model's covariates (Heinzl and Mittlbb, 2003). Besides, the probability envelop graph of residuals can be used to assess the model fit.

4 Results and discussion

4.1 Descriptive analysis

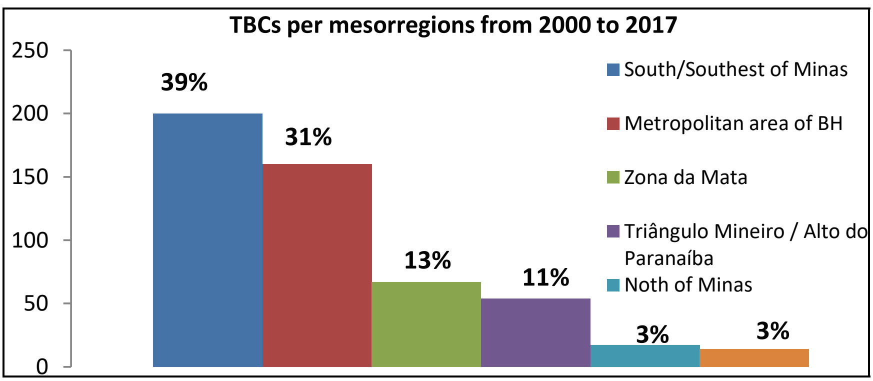
The TBCs registered in the InovaData-MG project corresponds to 521 companies created between 2000 and 2017, including incubated, graduated and resident companies. Of these, 113 represent emerging technology-based companies (ETBC) linked to pre-incubation, incubation, acceleration or other programs that were born during the study period, while 83% (94) of them were created in 2010 (Graph 1), when the start of these companies' most abrupt growth is evidenced.

Graph 1 Growth of incubated TBC between 2000 and 2017 (see online version for colours)



Source: InovaData-MG Census database from 2019

Graph 2 TBC per mesoregions of Minas Gerais (see online version for colours)



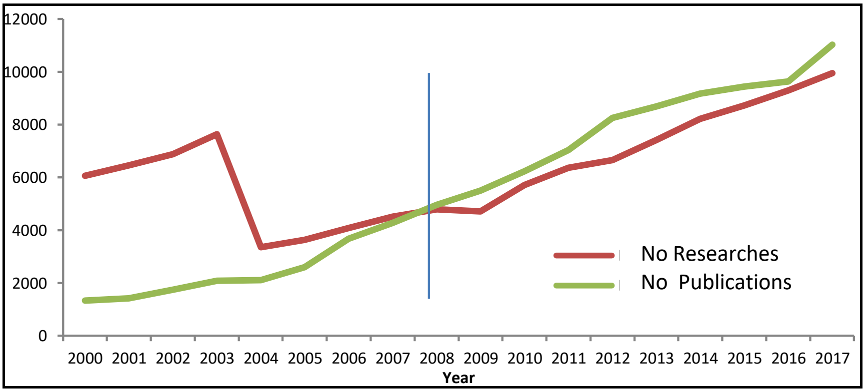
Source: InovaData-MG

The TBC count by mesoregion ranges from 1 to 19, which indicates that the approximation of the Normal distribution would not be adequate. The Shapiro-Wilk test confirmed the non-normality of the variables. The mean and variance values are not close, indicating the need for an adjustment of the model.

An analysis of the ETBC linked to pre-incubation, incubation, acceleration or other programs distribution within the 12 mesoregions of MG indicates that 70% of them are concentrated in the south/southwest of MG and Metropolitan Belo Horizonte (Graph 2). These data reinforce that the number of TBC varies considerably between the mesoregions. In fact, some regions, such as 'Jequitinhonha Valley', 'Mucuri Valley', 'West of de Minas Gerais', among others, do not register the occurrence of TBCs during the period covered in the study.

The relationship between academic researchers and the number of publications exceeds one publication per researcher in the most intense period of generation of incubated TBC (Graph 3), which shows increasing researcher productivity, as publications increase more than the number of researchers.

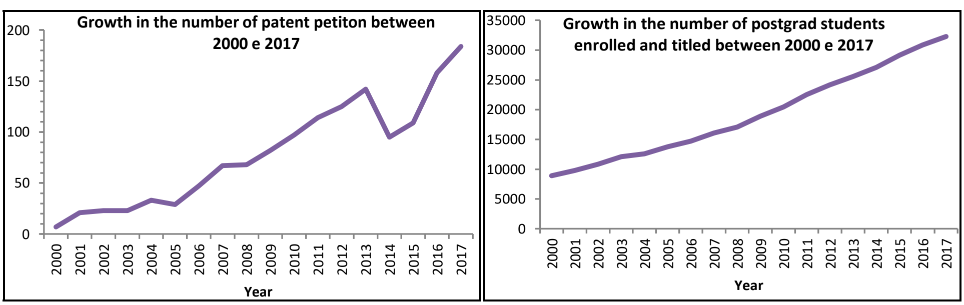
Graph 3 Growth in the number of publications and researchers between 2000 and 2017 (see online version for colours)



Source: CAPES (2018)

The numbers of university patent petitions (applications submitted), between 2000 and 2017, grew 20 times, from seven applications to 144. In this period, the community of postgrad students increased more than 300% (11,000 to 35,000 students). Graph 4 shows these relationships.

Graph 4 Growth in the patents petitions and postgrad students enrolled and titled (2000 to 2017) (see online version for colours)



Source: CAPES (2018)

Table 3 Correlations between explanatory variables

	TBC	*Patent petitions*	*Academic publication*	*Academic research*	*Postgrad student*	*Scholarship*	*Population size*	*RGDP*
TBC	1.0000							
Patent	0.2097	1.0000						
Publications	0.1925	0.9346	1.0000					
Researchers	0.1975	0.7748	0.7659	1.0000				
Postgrad st.	0.2396	0.9226	0.9148	0.9121	1.0000			
Scholarship	0.1782	0.9283	0.9614	0.7941	0.9166	1.0000		
Population	0.4627	0.7449	0.7061	0.8618	0.8658	0.6992	1.0000	
RGDP	0.3937	0.8842	0.8556	0.7511	0.8837	0.8726	0.8230	1.0000

The numbers of patent petitions and of postgrad students Both variables have similar behaviour curves over the period, though at different scales. The correlations between these variables are shown in Table 3, which presents the correlations between explanatory variables. Values close to 1 indicate a strong association mainly between covariates. The multicollinearity between the explanatory variables, as they are highly correlated, generates inflation in the variance of the estimators in the model.

Aiming to reduce the multicollinearity, the explanatory variables were reformulated as follows: 'patents/publications', 'postgrad student/researcher' and 'postgrad scholarship/researcher'. The real gross domestic product (RGDP) per capita was initially considered a proxy. Table 4 shows the correlations between these new variables.

Table 4 Correlations between the reformulated explanatory variables

	TBC	*Patent petition/ publication*	*Postgrad student/ researcher*	*Postgrad scholarship/ researcher*	*Time*	*RGDP per capita*	*Population size*	*RGDP*
TBC	1.000							
Patent/ publication	–0.2088	1.0000						
PG stud./ researcher	0.1478	–0.0133	1.0000					
Scholar/ researcher	0.1839	–0.1943	0.1829	1.0000				
Time	0.0464	–0.4446	0.6028	0.5702	1.0000			
RGDP/ capita	0.2779	–0.2289	0.1684	0.7940	0.4112	1.0000		
Population	0.4627	–0.0586	0.0506	0.0648	–0.1321	0.3830	1.0000	
RGDP	0.3937	–0.0892	0.1682	0.4720	0.1763	0.7585	0.8230	1.0000

Figure 3 Log of the number of TBC versus numeric covariates

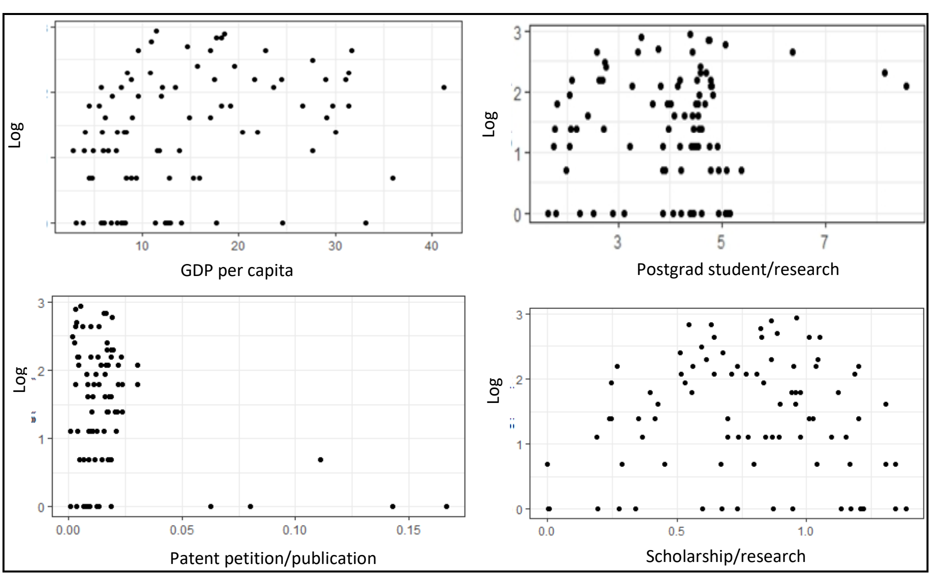
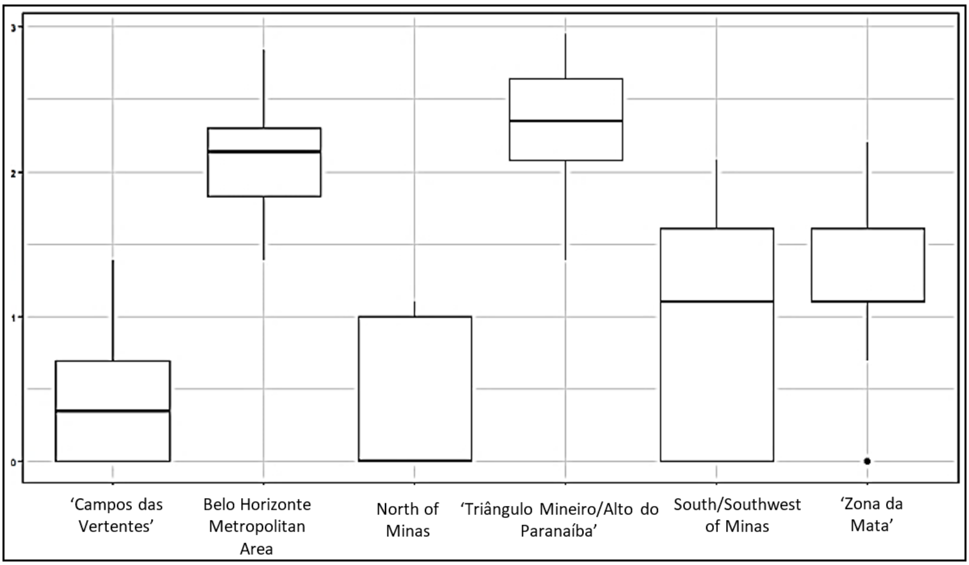


Figure 3 shows how the covariates relate to the response variable on the logarithmic scale. The graphs show that the ratio between researcher and postgrad student is negatively related to the number of TBCs. There is a decline in the scatter plots concentration points as in a trend curve with a negative slope. In contrast, the increase in real GDP per capita is positively related to the TBC logarithm.

Figure 4 contains the box plot graphs of the TBC logarithm highlighting the Belo Horizonte Metropolitan region and the South/Southeast of Minas with their boxes above the others, showing a greater number of TBC in such regions.

Figure 4 Box plot of log (TBC) per mesoregion of MG



4.2 *Model adjustment*

As expected, in its original form, the model adjusted with all covariates showed multicollinearity given the high correlation between variables as shown in Table 4. This original approach resulted in a model where the control variable RGDP per capita and the number of academic publications and number of postgrad scholarships explain the number of TBC. However, the effect of the measured multicollinearity showed values above 10, rendering this original approach not viable. Thus, it was decided to replace RGPD per capita by population size as control variable and work with the rest of the variables on a scale per capita whenever possible.

Having said that, a new adjustment to the model was necessary and the variables that had the biggest inflation variance factor were conceptually reformulated, creating the following new variables:

1 patent petitions by academic publications, seeking to measure the production of knowledge that generated commercial value

2 postgraduate students by academic researchers, seeking to measure how much each mesoregion would be more focused on teaching or on researching

3 postgraduate scholarship by academic researcher, seeking to measure government incentives in academic production.

The other variables (X_{u1}, X_{u2}, X_{u3}, X_{u4} and X_{u5}) as in Table 1 were considered per capita.

The RGDP per capita variable did not show relevance in the presence of population size. As a consequence, the final model, removing the RGDP per capita variable and including population size and time (number of years across the research period) is shown in Table 5. The mesoregions also did not show significance when considering population size. Therefore, this adjusted negative binomial regression model also considers the over dispersion of the TBC data.

The coefficient for determining the regression over the other explanatory variables is shown in Table 6, demonstrating how much the coefficient variance is increased by its collinearity. In this case, all variables had variance inflation factor (VIF) values less than four. For this adjustment, the residual deviation was 86.048 and the Akaike information criterion (AIC) was 456.94, lower than the model before adjustment, accentuating the best quality of this model. Additionally, that the Nagelkerke's pseudo-R^2 value, for models whose dependent variable is value count as in the negative binomial regression, was 54.77%. In other words, the model can explain approximately 55% of the variability of the dependent variable. Thus, the proposed empirical model appears to be valid and with a reasonable level of explainability.

Table 5 The adjusted negative binomial model with overdispersion

	Coefficient	*Exp (coef.)*	*p-value*	
Interception (β_o)	0.9315	2.5383	0.0007	***
Population	1.593×10^{-7}	1.0000	0.0000	***
I (postgrad student/researcher)	0.1981	0.8716	0.0113	*
I (postgrad scholarship/researcher)	–0.8573	0.4243	0.0311	*
I (patent petition/publication)	–0.1374	1.2191	0.0021	**
Dynamic component	–0.2030	1.0395	0.0044	**
(Time = no. of years)	0.0387	0.8163	0.0298	*

Notes: Statistical significance: 0 '***' 0.001 '**' 0.01 '*' 0.05 ∓. The coefficient was divided by 100 mil habitants.

Table 6 Coefficient of determination of the regression for the variables of the adjusted negative binomial model with over dispersion

	VIF
Population	1.1696
I (postgrad student/research)	2.1204
I (scholarship/research)	3.2448
I (patent/publication)	1.2207
Dynamic component	1.0381
(Time = no. of years)	1.7084

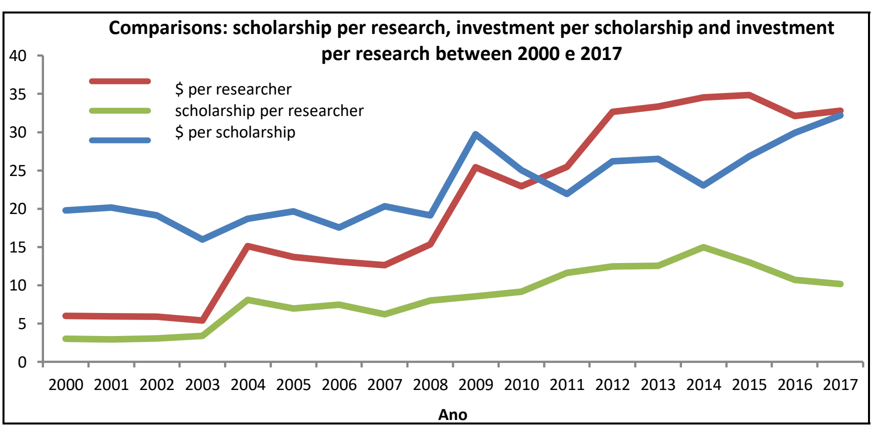
The interpretation of an explanatory variable of the negative binomial model is made from the exponential of the estimated coefficient, as previously stated. Thus, the effect of time on the appearance of TBC is positively significant, and the increase in one year generates an increment of 18% in the average appearance of TBC. In other words, this suggests that the lapse of time, interpreted as the maturity of the region's ecosystem, may influence the determination of the TBC average appearance. Similarly, Fritsch (2008) found that start-up rates can have a statistically significant impact on a region's economic growth over a period of up to ten years.

All the variables reconfigured, 'postgrad student by researches', 'scholarship by researchers' and variables 'patent by publication' also showed statistical significance with a *p*-value less than 0.05 and 0.10, respectively.

The 'postgrad student by researches' shows that a unit increment of postgrad students per researcher, results in an increase of 13% in the average number of TBCs. Therefore, the increase in number of postgrad student increases considerable the researches and publications in the technology areas. The majority of the scientific production is conducted by the postgrad students, although oriented by the doctoral professors. Audretsch et al. (2012) previously used the same indicator in his study. However, they considered all university students (undergrad and grad). In this case, an increase in the number of students by professors would reduce the ability to conduct research, as the undergraduate student does not participate in research projects and demand attention mostly in teaching.

The 'postgrad scholarship by researchers' shows that by increasing one unit in the ratio, the expected average number of TBCs decreases by 58%. The increase in the ratio also happens by decreasing the number of researchers (doctoral professors). As expected, the average number of TBCs decreases by 58%. The scholarships granted in Brazil represent less than two minimum salaries (less than 400 dollars per month) and requires full dedication (CAPES, 2020). Such work conditions are not attractive, especially for entrepreneurs in technological areas. Notwithstanding, it may stimulate the academic carrier and not the entrepreneurship.

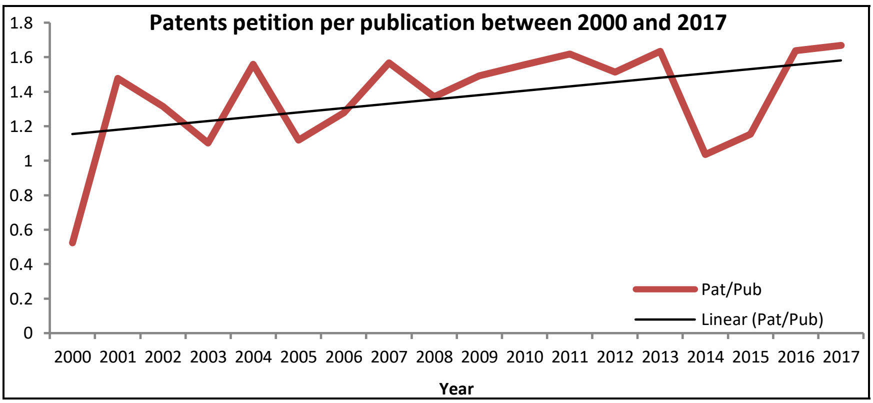
Graph 5 CAPES scholarships comparative in MG (see online version for colours)



Source: CAPES (2018)

In this study, the number of scholarships awarded considered are the ones granted by CAPES, whose overall trend grew slightly in the period, in spite of a decrease from 2014 (Graph 5). Additionally, postgrad scholarships data from other funding agencies[1] were not available, even though their contribution plays an important part in research investment in MG. Additionally, the financial value of CAPES incentives in the state could not be applied in this model because the data made available are not disaggregated by mesoregion, but only as a single value for the entire state. The growth tendency of this figure for the state is presented in Graph 5. These arguments might justify the very few publications in Brazil and especially in Minas Gerais on this regard.

Graph 6 Minas Gerais universities patents petitions per publication (see online version for colours)



Source: INPI (2019) and SCOPUS (2019)

The ‘patent petition by publication’ also shows that by increasing one unit in the ratio, the expected average number of TBC decreases by 78%. Knowing the importance of patenting, this result indicates that the negative relationship of this ratio can be related to Brazilian publications considered in this variable. The increase in the ratio occurs when publications decrease, and it can indicate a decrease in scientific production. Additionally, in this case, the publications included in this variable denominator consider all areas of knowledge such as philosophy, social sciences, among others, and not only those areas that are likely and more prone to patents. In addition, as stated by the Brazilian Industrial Development Agency (Agência Brasileira de Desenvolvimento Industrial – ABDI) (2018), there is a vast inventory of patents maintained without application. Such situation generates academic merit, but mischaracterises the objective of the indicator that attempts to measure the value realisation potential of the knowledge created and innovation. Additionally, this condition has the potential to obstruct the advance of certain technologies, since the granting of patents reduces the chances of exchange of this specific knowledge (Choi and Phan, 2006), since it protects it.

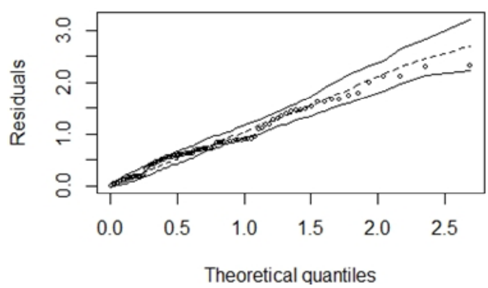
The ‘patent petition by publication’ variable in the period (Graph 6) suggests that additional elements should be are taken into account to be conclusive. One of such elements is the time lag in the patent application process, which is a lengthy a process in Brazil. Another element is that the data measure the effort to innovate, and not actual patents granted. So, this number could be significant higher than the granted ones. Choi and Phan (2006) still claim that many entrepreneurs, due to cost and time restrictions, start their ventures without the benefit of patents and only apply for registration after they have been successful in the business.

Leydesdorff and Meyer (2010) also defend the recent decline in university patenting due to the expensive and time-consuming process involved, with relatively small expected rewards, especially in Brazil. These facts help to mask the direct effects of patents on the emerging TBC. Similarly, to the present study, and using binomial regression, Horaguchi (2016) found that patent effect on new start-ups is negative, although he has indicated that new start-ups have a positive effect on patent applications.

4.3 *Model validation*

The model adjustment was validated using the envelope graph shown in Figure 5. The adequacy is considered correct when all points are between the envelope limits, as shown in Figure 5. This confirms and validates the interpretations made to the adjusted regression model.

Figure 5 Simulated envelope graph of the adjusted negative binomial model with overdispersion



As the sample unit studied data per year, it is also necessary to verify that there is no spatial and temporal correlation between the model residues. In case of any correlation detected, the assumption of data independence is violated and another type of model must be adapted.

Figure 6 Spatial and temporal correlation between the residuals of the adjusted model (see online version for colours)

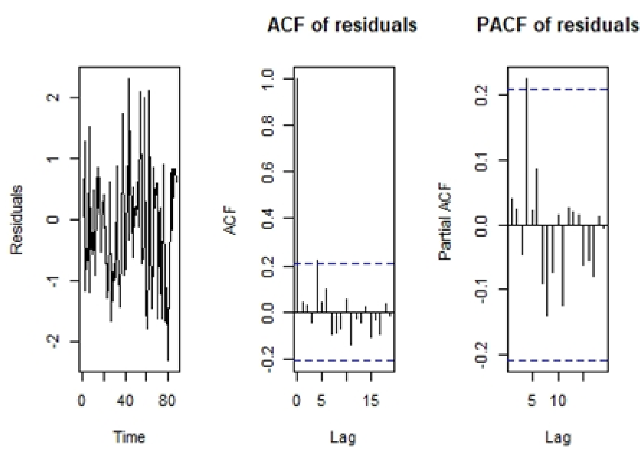


Figure 6 shows the residuals arranged by year, the autocorrelation graphs and the partial autocorrelation. Residues are not correlated with time, as there is no evident pattern in the first graph and the autocorrelations are within the 95% confidence bands. In addition to the visual analysis, the Box-Pierce test and the autocorrelation between the residue of a given year and any of the previous years were performed, and, for any lag, it was not significant at the 5% significance level. The spatial autocorrelation of residues was also tested using the Moran Index, shown in Table 7. The *p*-value greater than the 5% significance level indicates evidence of the spatial non-correlation of the residues.

Table 7 Moran Index

Moran Index	0.969
p-valour	0.036

5 Conclusions and implications

The study focused its analysis on knowledge production that creates value in the form of new TBCs that initiated their operation between 2000 and 2017, in the MG, based on data available in the census conducted by the InovaData-MG project. The explanatory variables referring to the state higher education institutions were restricted to those published on government public platforms. No additional data were collected during the study, which aimed to produce knowledge from existing Brazilian database. The Inovadata is still far from ideal, but is a start for exploratory studies in the region. The present study produced knowledge based on the use of open government databases and the sharing of information with other research groups, such as the MTC, at the UFV. Following the typology (data -> information -> knowledge) hierarchised by Wei (2003), the work contributed to the literature, generating more empirical evidence about the KPF for one the Brazilian regions, Minas Gerais.

The degree of explanation of the validated model shows its compatibility with the behaviour of the object under study. The study confirmed that the human capital (postgrad students) in universities has an influence in the creation of TBC, and that, in this context, researches activities act positively in this scenario, represented by the positive relation of number postgrad students (as in Table 8). Such evidences reinforce the importance of universities for the development of TBC, and that public policy may strengthen their connections. In fact, among the 521 TBC of the sample, 16.5% are spin-offs and, thus, created within universities in the region. According to Statista Research Department (2016), this percentage is similar to some European countries, such as Switzerland (18.1), Italy (13.5%) and Germany (12.5%).

Table 8 presents a summary result of the hypotheses proposed related to the model adjustments based on data collected. These results suggest that the university output contributes to the creation of TBC creation in MG especially through human capital (postgrad students) as suggested in other studies presented in Table 2, as H2 was confirmed.

The contribution through knowledge assets asset generated by the human capital of the universities in the form publications appear valid, as the positive relation of publications and the increase in TBC number was confirmed (H3). The recent increase in research quality in Brazil, as exposed earlier, fortifies that factor.

The negative relation found on the postgrad scholarships and the increase in TBCs, as explained earlier, appears as a concurrent factor in Brazil. Therefore, H5 was rejected.

As the data structure is space-time (longitudinal) the study also confirms that time, interpreted as the stage of maturity of certain regions of MG, have had a positive influence on the creation of TBC. This result suggests the importance of time as relevant factor for the evolution of knowledge in MG region, showing the importance of a mature habit to promote knowledge as it was measured. Similar finding is suggested by Gonzaga et al. (2020) that the maturity model can serve as a basis in a start-up ecosystem to propose policies and practical actions to improve their ecosystem over time.

Table 8 Hypothesis of the theoretical model

Hypotheses	*Original description*	*Adjusted hypothesis description*	*Results of the adjusted model*
H2	The number of postgraduate students in the region is positively related to the TBC number.	The ratio of postgrad student by research is positively related to the TBC number.	The positive relation was confirmed.
H3	The academic publication in the region is positively related to the TBC number.	The ratio of academic patent petition by publications is negative related to the TBC number.	The positive relation of publications and the increase in TBC number was confirmed.
H4	The academic patent petition in the region is positively related to the TBC number.		
H5	The postgrad scholarship in the region is positively related to the TBC number.	The ratio postgrad scholarship by research is negative related to the TBC number.	The negative relation of postgrad scholarship and the increase in TBC number was confirmed.
H1	The number of university researchers in the region is positively related to the TBC number.		

Findings also suggest that increasing the sample with more complete data would be extremely important to strengthen the model and better explore the analysis. Additionally, evidence demonstrates that the government's open data platforms are still scarce, of low quality and, therefore, lack transparency. This fact hinders knowledge production from data and information, because it poses a barrier to the improvement and democratisation of information. Based on this investigation and the strength of the university roles in Minas Gerais, it is possible to outline a new profile for universities in this digital, innovative and competitive context (Kuruczleki et al., 2016). One may expect the role of universities, as knowledge promoters, in a more participatory, interactive and entrepreneurial way in the geographic region (Etzkowitz, 2004; Mandrup and Jensen, 2017; Ranga et al., 2003). This new scenario will contribute to significant improvements to the current situation.

These changes are very relevant since the current public funding of Brazilian universities is unlikely to last and a new collaborative incentive model is needed for the nation to continue investing in knowledge and human capital. The relations and boundaries between public and private, science and technology, university and industry are in flux, where the universities and firms are assuming tasks that were formerly other sectors competences is increasingly a subject of science and technology policies at different levels (Etzkowitz and Leydesdorff, 2000).

The sources of innovation in a Triple Helix configuration are no longer synchronised a priori and do not fit together in a pre-given order, but they generate puzzles for participants, analysts, and policymakers to solve, since the network of relations generates a reflexive sub dynamics of intentions, strategies, and projects that adds surplus value by reorganising and harmonising continuously the underlying infrastructure in order to achieve at least an approximation of the goals (Etzkowitz and Leydesdorff, 2000). The entrepreneurial university encompasses and extends the research university (Etzkowitz, 2003b) and is not the 'commercialised university' but a university that encompasses the conservation and passing on of knowledge, integrating teaching, research as well as supporting innovation (Etzkowitz, 2003a).

Governments encourage the development of small innovative enterprises through priority financing of specific universities and legislative regulation, and they stimulate industry to develop and implement new innovative technologies and universities and industry can partially substitute for the state in the creation of an innovation infrastructure (Leydesdorff and Ivanova, 2016). Some studies also pointed that, in some developing countries, governmental policies may have important role (Bruton et al., 2018; Su et al., 2015), which may impact the performance of these new ventures. Therefore, some public policy can be suggested as the improvements in postgrad programs, reinforcement in activities that spread entrepreneurial culture, and incentives partnerships between industries and universities to promote the creation of new TBCs.

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Notes

1 Such as Minas Gerais State Research Support Foundation (*Fundação de Amparo à Pesquisa do Estado de Minas Gerais – Fapemig*) and National Council for Scientific and Technological Development (*Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPQ*).

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