Perspectivas em Políticas Públicas

SPACE INDUSTRY X SPACE EDUCATION IN BRAZIL: GEOGRAPHICAL (MIS)MATCHES AND OTHER PATTERNS

INDÚSTRIA ESPACIAL X EDUCAÇÃO ESPACIAL NO BRASIL: (DES)COMBINAÇÕES GEOGRÁFICAS E OUTROS PADRÕES

INDUSTRIA ESPACIAL X EDUCACIÓN ESPACIAL EN BRASIL: DESCONGESTIONES GEOGRÁFICAS Y OTROS PATRONES

Andrea Cabello[1]

Michele Cristina Melo[2]

Lucia Helena Freitas[3]

ABSTRACT

We investigate Brazilian Space Industry's tie to its higher educational enrollment and see if patterns similar to those found in the industry emerge, allowing us to estimate future trends. We used education data of 2022 from authorized Astronautical Engineering courses/majors from Inep and Capes, the Brazilian regulatory branches for education. Regarding space companies, we used the secondary data from the analysis performed by Cabello et al (2023). The industry is a lot more territorially concentrated than university enrollment in the field, and this does not favor the sector's development. The number of aerospace engineering graduates is probably higher than the sector's demand in non-heated years, probably due to the sector's heavy dependency on government procurement. This leads to a mismatch between companies and universities may have very severe consequences for long term development and calling for a well-articulated industrial-technological-educational policy.

Keywords: Space Industry; Space Education; technology clusters.

[1]Doutorado em Economia, UnB. Departamento de Economia, UnB. http://orcid.org/0000-0003-1489-0676. http://lattes.cnpq.br/4731226594888669. andreafc@unb.br

[2]Doutorado em Economia, UFF. Advocacia Geral da União. https://orcid.org/0009-0005-4861-724X. http://lattes.cnpq.br/6481305976565519. michelecsmelo@gmail.com

[3]Doutoranda em Economia, UnB. Ministério do Desenvolvimento, Indústria, Comércio e Serviços. https://orcid.org/0009-0002-9274-1836. http://lattes.cnpq.br/5836600779084304. luciah.michels@gmail.com

RESUMO

Investiga-se o vínculo da indústria espacial brasileira com o número de matrículas no ensino superior e verifica-se se os padrões encontrados na indústria se repetem, permitindo-nos estimar tendências futuras. Utilizamos dados quantitativos de educação de 2022 de cursos/disciplinas autorizados de Engenharia Astronáutica do Inep e da Capes, órgãos reguladores brasileiros da educação. Em relação às empresas espaciais, utilizamos os dados secundários da análise realizada por Cabello et al (2023), oriundos dos relatórios da AEB e da Rais. A indústria é muito mais concentrada territorialmente do que as matrículas universitárias na área, e isso não favorece o desenvolvimento do setor. O número de engenheiros aeroespaciais é provavelmente superior à procura do setor em anos não aquecidos, provavelmente devido à forte dependência do setor dos contratos públicos. Isto leva a um descompasso entre empresas e universidades que pode ter consequências muito graves para o desenvolvimento a longo prazo e exige uma política industrial-tecnológica-educacional bem articulada.

Palavras-chave: Indústria Espacial; Educação Espacial; clusters de tecnologia.

RESUMEN

Investigamos la relación de la industria espacial brasileña con su matrícula de educación superior y analizamos si surgen patrones similares a los encontrados en la industria, lo que nos permite estimar tendencias futuras. Utilizamos datos educativos de 2022 de las carreras/especializaciones de Ingeniería Astronáutica autorizadas por el Inep y la Capes, las entidades reguladoras brasileñas de la educación. En cuanto a las empresas espaciales, utilizamos datos secundarios del análisis realizado por Cabello et al. (2023). La industria está mucho más concentrada territorialmente que la matrícula universitaria en el campo, lo que perjudica el desarrollo del sector. El número de graduados en ingeniería aeroespacial probablemente supere la demanda del sector en años sin calefacción, posiblemente debido a la fuerte dependencia del sector de la contratación pública. Esto genera un desajuste entre empresas y universidades que puede tener graves consecuencias para el desarrollo a largo plazo y exige una política industrial, tecnológica y educativa bien articulada.

Palabras clave: Industria espacial; Educación espacial; clústeres tecnológicos.

1 INTRODUCTION

Space education is advancing all over the world both at graduate and undergraduate levels. New countries have established their own space programs, as more than 70 countries now have their own space agency, technology has advanced and applications multiply, signaling an auspicious time for the space sector and, therefore, astronautical engineering education and other related fields.

This growth has been following the increased demand for trained engineers as the scope of space technology has grown beyond government projects and prospects in the private market are promising. In many countries, government demand is still robust such as the United States, but private launches and rockets are increasingly successful, suggesting the beginning of a new golden age for the sector.

Scientific literature posits a symbiotic relationship between universities and industry, especially in successful clusters. An economic cluster is a geographic concentration of interconnected companies, which includes business throughout the production chain, both upstream and downstream and associated organizations like research and teaching institutions in a particular field or industry. These entities benefit from being close to each other through constant contact, shared infrastructure, skilled labor pools and academic contacts, knowledge spillovers, collaborative opportunities and ties, and tacit knowledge exchanges which can lead to increased productivity, innovation, and competitiveness and cooperation. That is the case for, example, for innovation literature and its systems of innovation view (Freeman, 1995; Edquist, 2005; Lundvall, 2007) or its triple helix concept (Leydesdorff & Etzkowitz, 1998). The idea is that for industry to flourish, it needs an articulated relationship with training, education, research and innovation-focused institutions (Mazzucato, 2014).

Feser (1998) is adamant that "no theory of industry clusters, per se". What the literature typically discusses is how the interaction of firms and local institutions may lead to increased firm competitiveness (Porter, 1990). Padmore & Gibson (1998) point out that not every geographical concentration is a cluster. According to these authors, "Clustering is a function of the number and quality of linkages among firms and with

other elements of the economy. It is the linkages that enable a vigorous level of innovation, customer satisfaction and other benefits." They also point out that a successful cluster depends on how well these factors interact to lead to a cluster competitiveness.

John & Puder (2006) distinguishes between technology clusters versus industry clusters, claiming that they demand different capabilities and lead to different sources of regional advantage.

There are many examples of studies of space sector clusters in the world, such as this is a sector that typically clusters. Beaudry (2001) and Vorley et al (2022) analyze the UK's case, while George (2019) describes the space economy impact on the state Florida in the United States. Other interesting examples are Krupnov & Batyrshin (2007)'s description of the Russian case, Siddivò & De Chiara (2012) comparison of China's and Italy's space clusters and Paone & Sasanelli (2016)'s analysis of opportunities for the Australian space industry and its cluster.

In Brazil, the most articulated innovation cluster is the space-aeronautical cluster in São José dos Campos, in the state of São Paulo. This calls attention to the space industry ability to connect to industry in both research, innovation and educational levels.

Following Cabello et al's (2023) effort of mapping the Brazilian private space industry, we aim to investigate its tie to higher educational industry and see if patterns similar to those found in the industry emerge, allowing us to estimate future trends in terms of clusters. As of now, the literature identifies only in one cluster in the space sector in Brazil, the already mentioned space-aeronautical cluster in São José dos Campos, in the state of São Paulo. However, recent developments by government policies, space companies' activities and research and education institutions suggest that new clusters may be forming. So, our goal is to investigate how closely research and education institutions follow private space industry patterns in other to evaluate the sector development as whole in the country.

The paper is divided as follows: section discusses our data, while section three discusses space education and industry in Brazil, focusing on similarities and

dissimilarities, especially of a geographical nature. Section four brings our results and conclusions.

2 DATA

Our data comes from the Higher Education Census provided by the National Education Research Institute (*Instituto Nacional de Estudos e Pesquisas Educacionais – INEP, in Portuguese)*, which is the regulatory branch of the Brazilian Ministry of Education in charge of evaluating educational systems and the quality of education in Brazil. We used education data from 2022 from authorized Astronautical Engineering courses/majors.

For graduate programs, our data comes from Coordination for the Improvement of Higher Education Personnel – CAPES (or *Coordenação de Aperfeiçoamento de Nível Superior, in Portuguese*), which is the regulatory branch of the Brazilian Ministry of Education in charge of evaluating educational systems and the quality of graduate education in Brazil. Again, we used education data from 2022 from authorized space-related graduate programs.

Our goal with these two sets of educational data, that is i) data from undergraduate Astronautical Engineering courses/majors and ii) data from space related graduate programs is to show how space-related education has developed in Brazil.

Graduate programs tend to be more specific on their scope, as they, by their own purpose, are more specialized in nature. In terms of method, this means that we did not need to go classify them in order to establish the courses/majors that could be considered space related.

However, for undergraduate courses, we felt the need to consider two classifications: a strict one, with only aerospace or astronautical engineering major/courses, which are more recent, following a worldwide trend, as we shall discuss ahead; and an ample one, with other major/courses such as aeronautics,

telecommunications, astronomy and related fields whose content were space related, albeit not specialized in it.

Regarding space companies, we used the secondary data from the analysis performed by Cabello et al (2023), so we cite them rather than their primary source. They do a wonderful job of mapping space companies in Brazil. This is a very difficult task, as it involves identification and privacy issues. That is, it is hard to identify which companies are active in one sector (and it gets harder, the bigger the sector is) and many times, there is no public information about who these companies are.

Cabello et al (2023) bypassed these problems by using the Brazilian Space Agency's (*Agência Espacial Brasileira – AEB – in Portuguese*) supplier catalogue as a proxy for active space companies. This was possible because of peculiarities of the space sector – it is a very small sector with great entry cost – both of financial and technological nature. Companies are also highly dependent on government procurement (Cabello et al, 2021), which means that all space companies are very likely listed in AEB's supplier catalogue, something unlikely for other sectors in the economy.

Cabello et al (2023) also proposed a very useful distinction, that is, between typically space companies, that is, those that are active only in the space sector; and not that are not typically space companies, in other words, those that are active in the space occasionally. The latter are, for example, defense or telecommunications sector companies that when opportunity comes, participate in public calls or bids for space projects, but do not have space as their main area of expertise.

In a way, this resonates with our proposal of an ample classification of space-related courses/majors. Although the sector has been demanding professional for years, government procurement instability may have not led to a large and stable enough demand to generate professionals with abilities specific enough, in a way that may even hurt the human capital availability and the sector's growth prospective. This is something for us to consider when we analyze our data.

In terms of method, we shall compare then these two sets of data: our educational data, to consider out skill and human capital formation supply on one

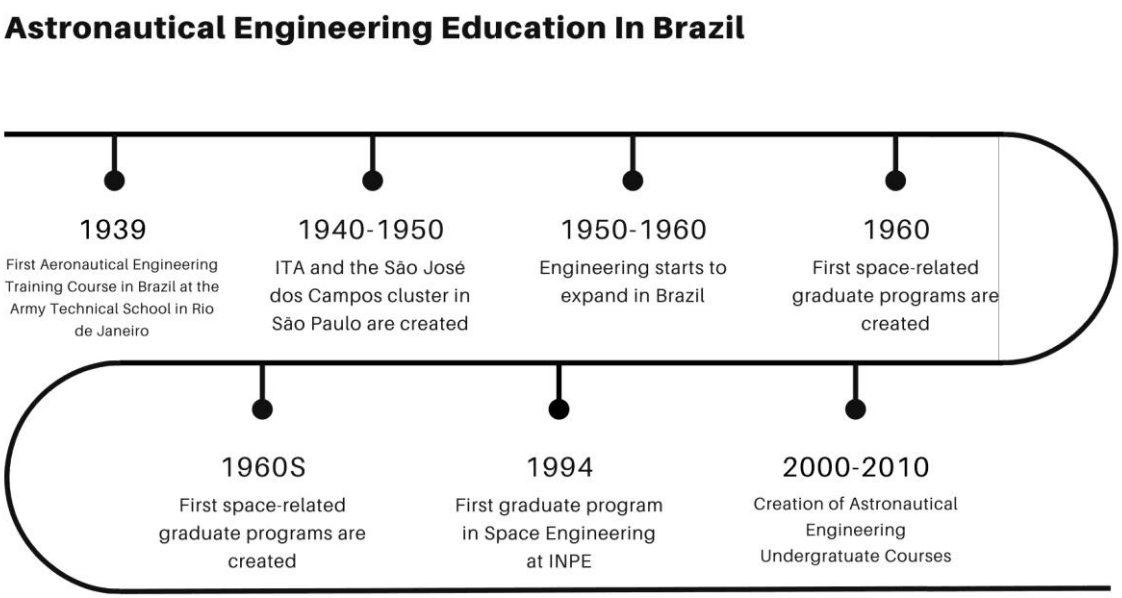
hand; and our companies' data, to consider the demand for these skill on the other hand.

3 Space education and industry in Brazil

When it comes to astronautical engineering, things are recent, especially in Brazil. Just like elsewhere in the world, astronautical engineering started as a subfield in aeronautical engineering courses and departments. In Brazil, the most traditional institution is the Air Force Technology Institute (*Instituto Tecnológica de Aeronáutica - ITA, in Portuguese)* Although a pioneer in space research, ITA's astronautical engineering undergraduate course dates from 2010 (Paula et al, 2015). Other institutions created their own courses at the same time such as the Federal University of Minas Gerais and the Federal Universal of ABC (in São Paulo state).

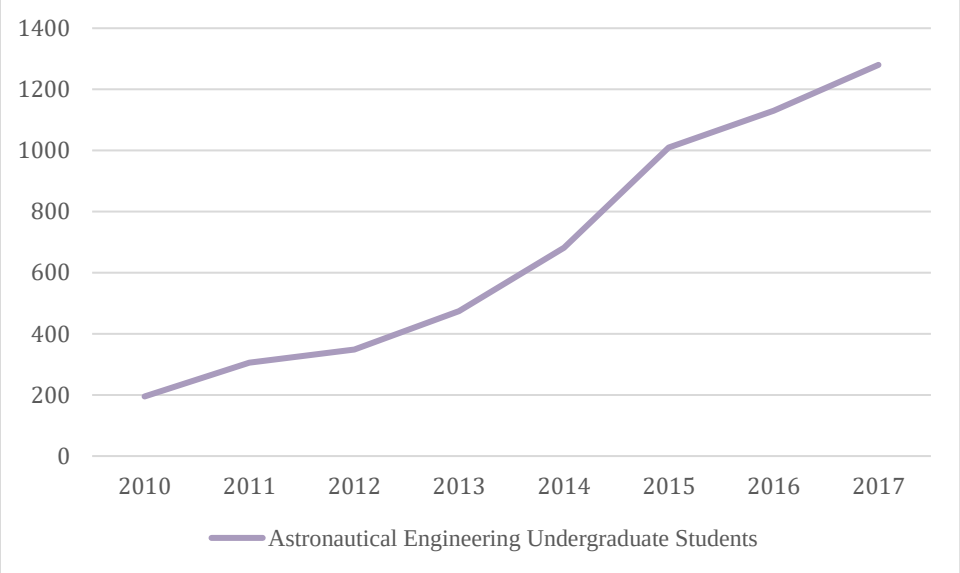
Figure 1 shows a simplified timeline of landmarks in astronautical engineering education in Brazil.

Figure 1 - Timeline of Astronautical Engineering major/course creation in Brazil



The number of Astronautical Engineering is still very scarce in Brazil, totaling 19 undergraduate courses. Typically, each course offers 50-100 openings a year, totaling less than 2.000 opening a year. For example, the number of Civil Engineering courses in Brazil is close to 200.000 openings a year, training 100x more engineers. Figure 2 shows the rapid increase in enrollment in astronautical engineering in Brazil in the 2010 decade.

Figure 2 - Astronautical Engineering Undergraduate Students in Brazil



Astronautical Engineering departments tend to be very geographically concentrated, following somewhat the pattern of space economic activity in Brazil (as it will be shown in Figure 6, in the space-aeronautical cluster in São José dos Campos, in the state of São Paulo). Most courses are located where the typically space companies are located (following Cabello et al (2023)'s classifications), while the other ones are located in states where the not typically space companies are located.

Figure 3 shows the location of space-related graduate programs while Figure 4 and Figure 5 show the location of the ample and the strict classifications of space-related undergraduate programs, respectively.

Figure 3 - Space-related graduate courses in Brazil

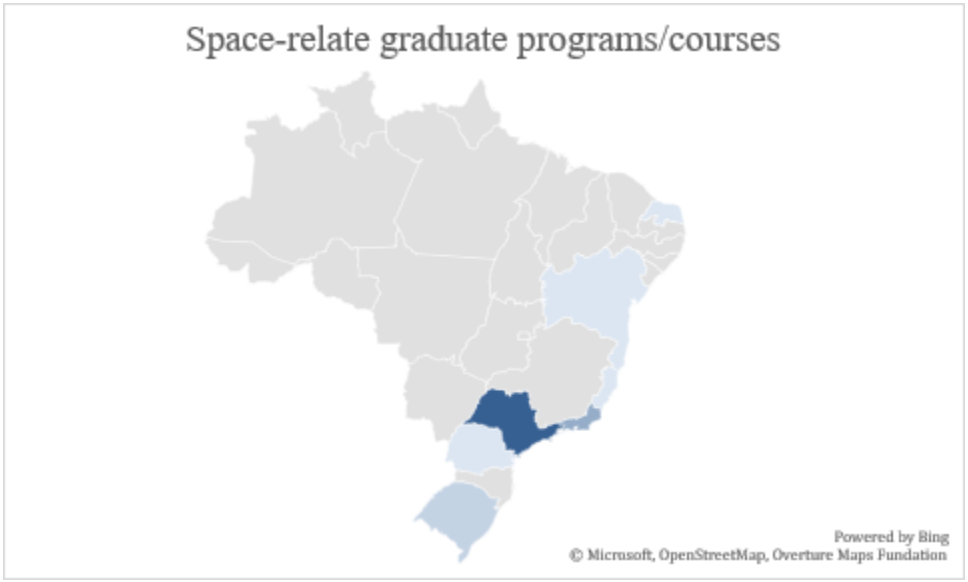


Figure 4 - Space-related undergraduate courses in Brazil (ample classification)

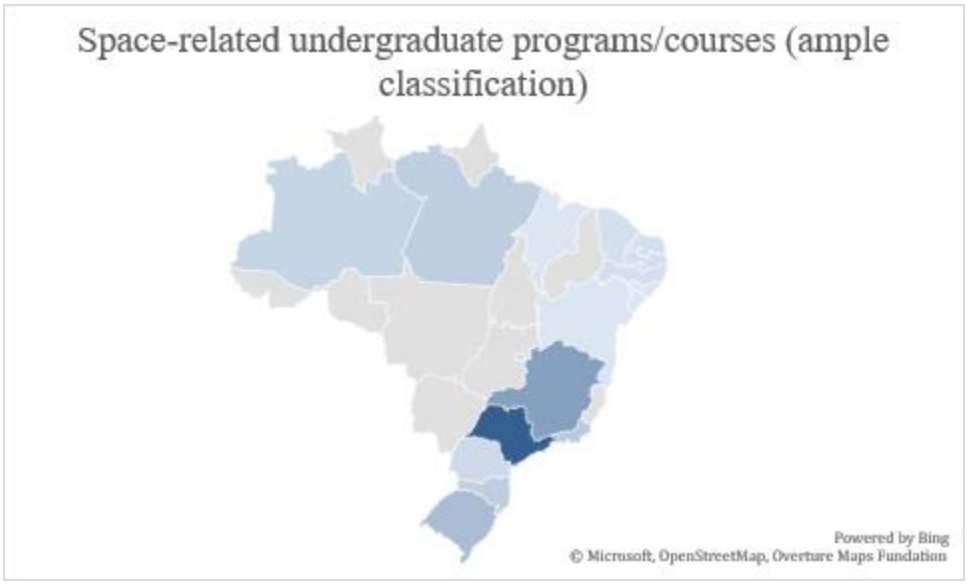
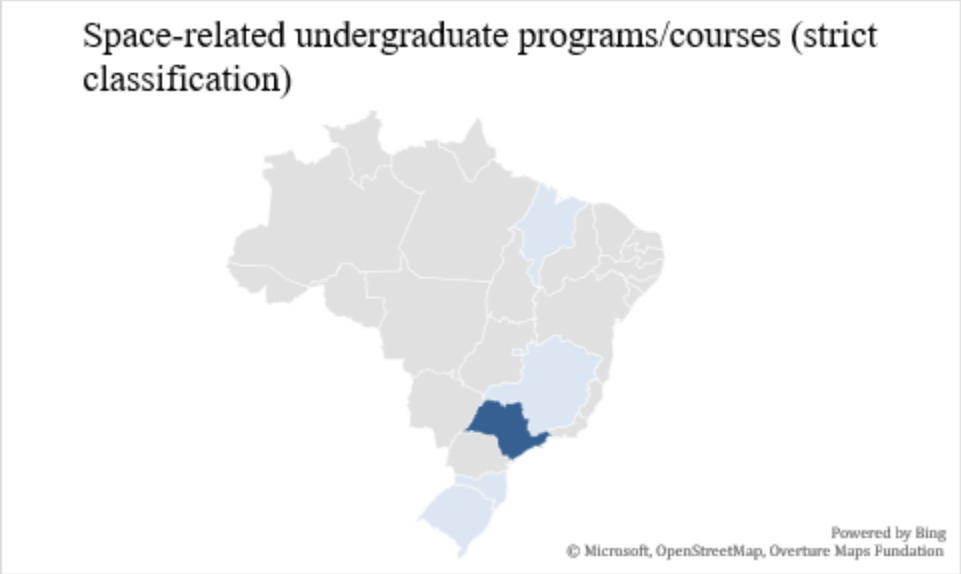
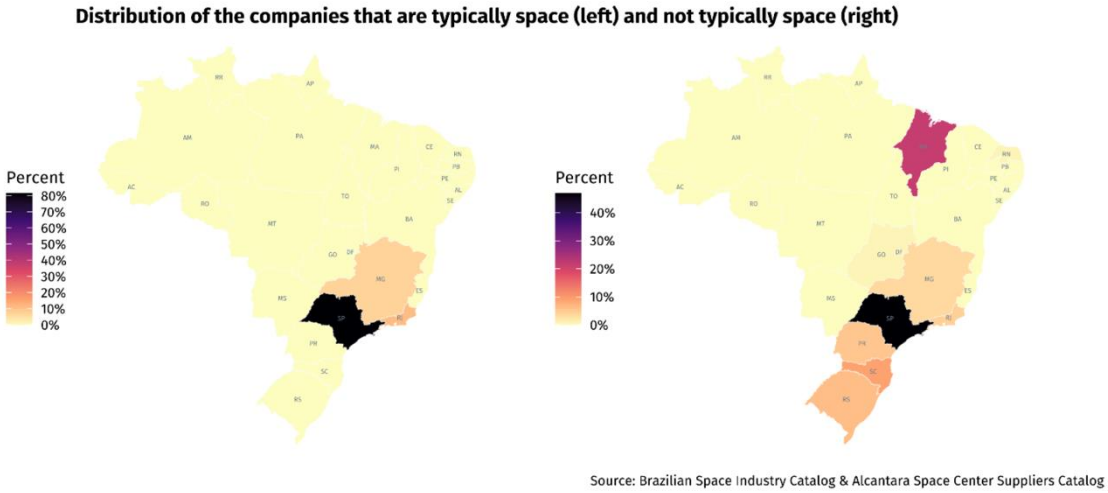


Figure 5 - Space-related undergraduate courses in Brazil (strict classification)



Data from Figures 3, 4 and 5 show that, especially when considered in a strict sense, space-related educational institutions are located close to space industry. The darkest state in all three figures is the state of São Paulo, where there is a well-known space and aeronautical industry cluster. Figure 6 shows the distribution of space companies in Brazil and how typically space companies and not typically space companies are distributed in the Brazilian territory.

Figure 6 - Distribution of Space Companies in Brazil



The geographical pattern of both undergraduate and graduate courses is very similar to the geographical pattern of the Brazilian space industry itself suggesting that: i) there seems to be only one clear industrial cluster in Brazil, the space-aeronautical cluster in São José dos Campos, in the state of São Paulo; ii) while we cannot speak of a space cluster outside of the state of São Paulo (Nakahodo, 2021), there seems to be an incipient symbiotic behavior between industry and educational institutions in other regions of Brazil as well, where those companies that are active in the space sector in a more transient way (the not typically space sector companies, in Cabello et al (2023)'s classification) are located.

An interesting location here is the Northeast of the country, where Brazil's two launching centers are located. This suggests that the proximity to government infrastructure – Air Force infrastructure and launching centers both in São Paulo and at the Northeast - attracts companies and seems to influence the creation of its astronautical engineering major, as most of the literature suggest (Xeidakis, 1994; Byrne, 2006; Grimson, 2010; Heikkinen et al, 2017).

In other regions of the country, the lack of attracting factors such as education institutions that could train professionals, government facilities that that could provide demand and a small industrial sector in its own has led to a non-existent presence of space companies. In other words, without a clear articulation between government demand and education institutions, space companies do not seem to flourish in Brazil.

4 Results and Conclusions

The space sector in Brazil is still very small and very geographically concentrated as it still very dependent on government procurement, and the development of making it a very unstable and risky business at times, (Moltz, 2015; Cabello et al, 2022) as it happens often in many countries. This leads to negative consequences for the sector and individuals who wish to join it and that may require an integrated industrial-technological-educational policy to adjust.

First, the industry is a lot more territorially concentrated than university enrollment in the field, and this does not favor the sector's development. Students migrate from their college city to cities with aerospace companies after graduating. This leads to a transaction cost, as many undergraduates are unable to do internships during the college years, lacking valuable experiences when they graduate and helping industry and academia develop a close professional and scientific relationship needed for technological development that goes beyond those institutions located in the São José dos Campos cluster

Second, the number of aerospace engineering graduates is probably higher than the sector's demand in non-heated years and we are not sure yet how it compares it to in heated years[4]. This has to do with a certain seasonality/volatility in government procurement, that obviously means that the number of graduates will not strictly follow the sector's demand due to its demand on government procurement.

[4] We do suggest this as a topic for future research.

This, together with the need to move elsewhere for a job in the sector means that many good candidates possibly quit before even joining the sector at all, either moving to companies in their own cities, companies in technologically other close (or even not-so close sectors) or even abroad, in a brain drain process, both regionally and internationally, hurting (regional) development even more.

That is, a mismatch between companies and universities may have very severe consequences for long term development. This is why a well-articulated industrial-technological-educational policy is necessary. However, Brazil is still maturing its industrial policy towards the space sector, both in terms of funding but also in terms of legal instruments (Pedrosa et al, 2024; Szimansk et al, 2024). That may help these companies prescind from government procurement and be more independent and even more international trade oriented.

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