THE EFFECT OF HUMAN CAPITAL ON ECONOMIC STRUCTURE

Deyvid W. Leite[1] and Leonardo C. B. Cardoso[2]

[1]Graduate Program in Applied Economics, Universidade Federal de Viçosa
[2]Department of Rural Economics, Universidade Federal de Viçosa

Abstract

It is well known that economic structure is linked to human capital and income growth. Even though disentangling how this relationship happens is crucial for policy screening, this still needs a better understanding. We shed light on this debate by investigating the nexus between human capital and economic structure at the micro-regional level. We exploit a significant expansion in the Brazilian federal network of technological and professional education since 2002 as an instrument for human capital. A second contribution is using a new measure of the economic structure – the Economic Complexity Index. Results indicated that higher levels of economic structure are associated with a larger stock of human capital. Regarding human capital, the expansion in federal institutes plays an important role in shaping micro-regional human capital and, consequently, economic structure. (JEL: I25; O11; F43)
Keywords: Economic structure, human capital, technological education.

Resumo

Sabe-se que a estrutura econômica está ligada ao capital humano e ao crescimento da renda. Embora desembaraçar como essa relação acontece seja crucial para a triagem de políticas, isso ainda precisa de uma melhor compreensão. Lançamos luz sobre esse debate investigando o nexo entre capital humano e estrutura econômica no nível microrregional. Exploramos uma significativa expansão da rede federal brasileira de educação tecnológica e profissional desde 2002 como instrumento de capital humano. Uma segunda contribuição é usar uma nova medida da estrutura econômica – o Índice de Complexidade Econômica. Os resultados indicaram que níveis mais elevados de estrutura econômica estão associados a um maior estoque de capital humano. No que se refere ao capital humano, a expansão dos institutos federais desempenha um papel importante na formação do capital humano microrregional e, consequentemente, da estrutura econômica. (JEL: I25; O11; F43)
Palavras-chaves: Estrutura produtiva, capital humano, educação tecnológica.

1 Introduction

It is widely accepted that human capital is connected with income growth. However, the manner this relationship takes place does not have a unique explanation. Economists diverge in the direction, intensity, and timing of such relation. Here we aim to shed some light on this debate by analyzing the effect of human capital on economic structure. As economic structure we mean what an economy is able to produce. That notion is a little subjective, so we use the concept of economic complexity (Hidalgo et al., 2007; Hidalgo, 2009; Hausmann et al., 2014). Hidalgo and Hausmann (2009) stated that higher levels of economic complexity are associated with higher levels of per capita income. Hence, a more complex economy presenting low per capita income tends to grow faster to be consistent with its economic complexity level. On the other hand, a less complex economy with high per capita income is likely to have diminishing growth to be compatible with its economic complexity level. They suppose those relationship especially when comparing economies presenting similar per capita income.

Romer (1990), Nelson and Pack (1999) and Cimoli (2005) affirmed human capital has a positive effect on income. However, they diverge in the size of the effect of human capital on income growth. They also take into consideration technology, which presents the need for high-skilled worker that can understand and generate technical progress. Furthermore, Zhu and Li (2017) stated human capital is the most important factor associated with economic structure.

According to Rodrik (2014), there are two keys for economic growth, improved human capital with good institutions; and the transition from a lower-productivity sectors to higher-productivity ones, the structural change. He also states these two keys for economic growth might not take place simultaneously, but both of them are required in the process of growth. Moreover, the structural change may start without the accumulation of human capital and better institutions. But, the improvement in human capital and institutions play a relevant role in boosting and maintaining the structural change.

Relating human capital to economic structure brings up an important issue, the similarity in their levels. As similarity, we mean economies with larger stocks of human capital tend to present better economic structures, while economies with smaller stocks of human capital are likely to have worse economic structures. So, a naive comparison would occur because there is a third factor affecting both variables or due to they influence each other. Hence, one way of identifying the causal linkage between the variables is to find a variation that is exogenous to human capital and not related to other factors influencing economic structure. Thus, an exogenous variation in human capital alters economic structure, showing the clear effect of the former on the latter.

In this strand, we highlight the expansion of the Brazilian federal network of technological and professional education since 2005. This network grew from 155 units in 2005 to 646 in 2021 and reached all the states in Brazil. In relative terms, in 2005 only 19% of the micro-regions had at least one unit of this network of education, while in 2021 that number went to 70% of the micro-regions.

Additionally, that expansion occurred through the creation or redesign of certain types of institutions. They are the federal centers of technological education (Centros Federais de Educação Tecnológica - CEFETs); the technical and agricultural schools linked to federal universities; a primary and secondary school named Colégio Pedro II; the federal technology university of Paraná state (Universidade Tecnológica Federal do Paraná - UTFPR), and the institutes of education, science and technology (Institutos Federais de Educação, Ciência e Tecnologia - IFs). These institutions are organized in units, known as *campus* or advanced *campus*. The major part of the expansion occurred by an increase in the quantity of institutes of education, science and technology. Thus, we henceforth use two terms: “IFs” to refer to all types of institutions, and “new IF” to refer to a new unit of these institutions.

The increase in the quantity of places in IFs may have played an important role in shaping human capital. According to Duflo (2001), large government-administered programs of investing in education may yield significant effects on human capital. Moreover, we take into consideration that expansion because it aimed to spread professional and technological education throughout Brazil, rising the stock of human capital. Then, we ask whether the rise in the stock of human capital influences economic structure at the micro-regional level.

The concept of economic complexity uses the diversity and ubiquity of exports to infer export sophistication, which indicates economic structure. It presents relevant progress related to objectivity and comparability and it can be measured at different levels. Furthermore, Hidalgo and Hausmann (2009) affirm economic complexity is an important predictor of income growth.

This investigation aims to expand the knowledge of economic structure by verifying whether there is an effect of human capital on economic structure in Brazilian micro-regions. That is because human capital tends to be unevenly distributed and locally bound (Audretsch and Feldman, 1996; Andersson and Johansson, 2010), which favors a micro-regional approach. A national or state level analysis could not capture the effect of a new IF on human capital. That is the reason why the analysis is based on micro-regions. Typically, a micro-region is a group of few municipalities that are close and connected to each other (Instituto Brasileiro de Geografia e Estatística, 1990). There are 558 micro-regions in Brazil and we aim to use all available data on them.

The hypothesis is the quantity of places in IFs is associated with human capital, while human capital affects economic structure. Hence, a rise in the quantity of places in IFs increases the stock of human capital, which in turn improves economic structure.

In addition to this introduction, this paper has been divided into four more sections. The second section presents the framework. The third section describes the identification strategy, giving some background of the expansion of IFs in the last two decades. Moreover, the third section also brings the database. The fourth section shows the results, providing an analysis of the relation between human capital and economic structure. The fifth section presents the conclusion of the investigation, offering a few remarks on the subject discussed.

2 Theoretical Background

2.1 Economic structure

Economic complexity is the total amount of productive knowledge an economy holds and how it uses the set of capabilities available. A capability is the ability to use a specific knowledge for doing something. In the process of expanding complexity, economies get new capabilities. These new capabilities tend to be akin to the already-available ones. In this strand, a larger stock of human capital may facilitate the process of increasing economic complexity by speeding up the acquisition of new capabilities.

A more complex economy has more capabilities, so that it can produce a wider set of goods and goods that few others can. For example, an economy producing bananas, steel bars and x-ray devices may have more capabilities than a similar economy producing only bananas and steel bars. The difference in capabilities is reflected by the quantity of produced goods and the difficulty associated with producing each good. Furthermore, economic complexity is based on both the diversity and the ubiquity of exported goods, as well as the level of connectedness among products.

Ubiquity is related to in how many places a good is found. The more ubiquitous a product is, the larger the possibility to find it. For instance, chemical products are less ubiquitous than plastic products, while plastic products are less ubiquitous than vegetables ones. Ubiquity level tells us how hard it is to produce and export a good.

Diversity indicates how many different goods an economy can deliver. A diversified economy should have mastered a large set of capabilities in order to produce a wide variety of products. For example, Sweden's exports have a level of diversity larger than New Zealand's, whilst New Zealand's exports are more diversified than Bolivia's. The diversity level provides information on the quantity of capabilities an economy has.

These two abilities can be viewed in a matrix considering the revealed comparative advantage (RCA). Balassa (1965) states RCA is a measure of the relevance of a good in an economy's export basket that controls for the economy size itself and each product's market share. Thus, the ubiquity and diversity levels are in the following matrix M_{ep}, in which 1 means that economy e produces good p with RCA, and 0 otherwise:

$$Ubiquity = k_{p,0} = \sum_{e} M_{ep} \tag{1}$$

$$Diversity = k_{e,0} = \sum_{p} M_{ep} \tag{2}$$

The Equation (1) indicates the number of economies producing each product with RCA, while the Equation (2) shows the number of goods an economy produces with RCA.

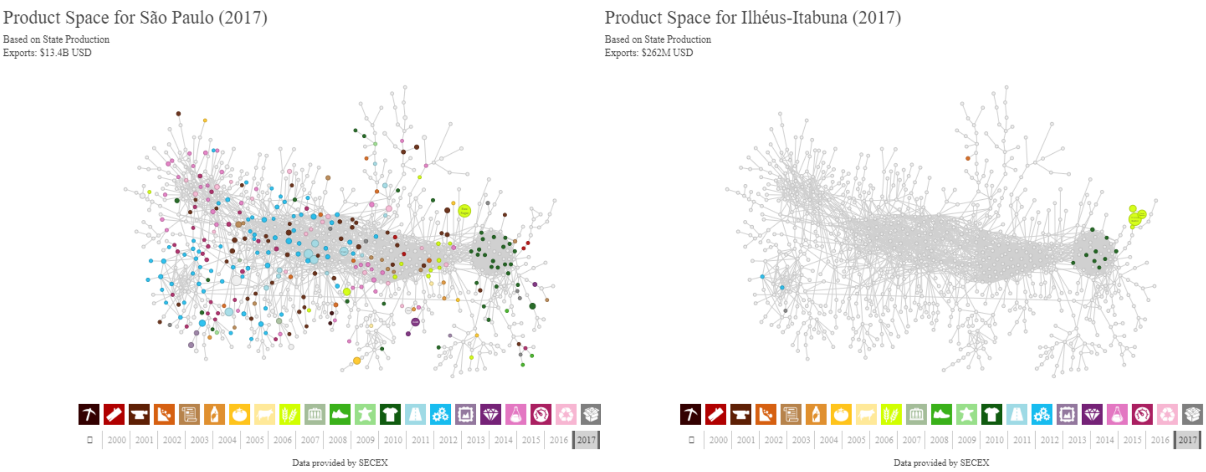
The level of connectedness among goods is related to how much knowledge is required for producing them. These three abilities compound the economic complexity, which is inferred by analyzing an economy's export basket. Thus, an economy is considered more complex as products in its export basket are less ubiquitous, more diversified and more connected to other products. Associating the diversity, the ubiquity and the connectedness of exported products leads us to a network that relates goods with $RCA \geq 1$ to economies. Considering an economy's export basket and the products in which it has advantages, the product space can be constructed.

The product space is a net relating goods according to capabilities required to produce each good. It also displays the proximity of products given the probability of certain products to be co-exported. If an economy has two products that are co-exported, it means a specific capability is linking these products. For example, an economy that produces cocoa paste is likely to also produce cocoa butter, since what is needed in both production are similar (Hidalgo et al., 2007). Thus, in the product space these two goods are close to each other and there is a line connecting them, showing they require related capabilities or inputs.

The product space displays in a stylized manner how goods are connected by capabilities and in which group of products the economic development is (Hidalgo, 2009). Products in the interior area of the product space tend to be more connected to other products than peripheral products. Producing goods that lies in the interior area of the product space indicates the availability of a large set of capabilities, which in turn are required to diversifying and producing non-ubiquitous products. Hence, the product space provides a visualization of the economic structure that is summarized by the economic complexity index (ECI).

In a product space, each node represents a good; the colorful nodes are the goods an economy exports with comparative advantages. The larger the node is, the higher the share of that good in international trade is. The colours and the icons at the bottom of the figure mean the groups of products. To introduce the product space, we display two panels of product space in Figure 1. The first panel is the micro-region of São Paulo-SP, which has the highest level of the ECI in 2017. The second one is the micro-region of Ilhéus-Itabuna-BA, which has the lowest level of ECI in 2017.

Figure 1: Product Space of the highest and the lowest economic complexity in 2017



(a) São Paulo-SP (Economic complexity = 53.19)

(b) Ilhéus-Itabuna-BA (Economic complexity = -6.206)

Note: The contrast between these two product spaces displays how these micro-regions differ in their capabilities, represented by their economic complexity indexes.
Source: Dataviva.

The micro-region of São Paulo-SP is able to produce lots of goods, which are from several groups of products and in the interior area of the product space. While the micro-region of Ilhéus-Itabuna-BA can produce few peripheral goods. The contrast between these two product spaces shows how these micro-regions differ in their capabilities, which is also represented by their economic complexity indexes.

In this context, we outline the relation between economic complexity and income growth. We take the micro-regions presenting the median of income per capita in 2005. This group of similar income per capita was divided into 10 subgroups according to their levels of economic complexity. Comparing the subgroup with the 10% better economic complexity to the subgroup with 10% worse economic complexity 12 years later yields that income growth was around 25% larger for the former. This result still holds when the comparison is different only in the percentile of better and worse economic complexity, at the 5% better and worse and at the 20% as well.

2.2 Human capital

Schultz (1961) and Becker (1962) introduced the concept of human capital as the set of skills and knowledge people use at production. According to them, investment in human capital is a source of economic growth and better earnings. Moreover, they explained certain sorts of investment in human capital and underlined the effects of formal schooling and on-the-job training. Schultz (1961) affirmed formal education is central in the process of economic growth, while Becker (1962) stated schooling and on-the-job training have similar effects on rising a person's earning.

In addition, Oketch (2006) stated investment in human capital presents three sorts of benefits. First, there are monetary returns to education, which means the individual profitability of human capital. Second, non-monetary returns to education, that is, effects on individuals' consumption and learning. Third, external returns to education, which are the social benefits of human capital, such as democracy and political stability.

According to Nelson and Pack (1999) and Cimoli (2005), increasing human capital stock is a way to improve the learning capacity, which predicts the structural change. Moreover, the change in economic structure takes place in economies with plenty of capabilities, not only with machines, tools and blueprints together. Romer (1990) suggested that human capital also affects technology growth by expanding innovative capacity. According to his approach, a few skilled people work for developing technology, rather than making final-output goods. That kind of jobs are related to cognitive skills and not to the quantity of education.

In the international literature, vocational and technological education was associated with human capital and economic growth (Yuen, 1993). Further, Yuen (1993) and the Ministry of Education of Taiwan (2014) argued there is a causal link between increases in vocational and technological education and the economic growth in Taiwan since 1950s. On the other hand, Nilsson (2010) claimed vocational education might be one of the drivers of growth but not more important than general education.

In addition, Icart and Rodríguez-Soler (2017) highlighted the strong association between vocational education and training with innovation in industrial small and medium companies. Furthermore, Rosenfeld (1998) underlined the role of public technical institutions and described them as a source of expertise and knowledge, which makes their graduates to react to technological change as well as to alter the rate of technology adoption. And, Toner (2011) emphasized the relation between the skilled vocational employees and the performance in exporting products that are intense in those skills.

In Brazil, the vocational and technological education is compounded of private and public institutions and the latter are federal, state or even municipal funded (Souza et al., 2015). Here we focus on the federal-funded institutions because they present certain features of the world's top systems of vocational and technological education. For instance, providing opportunities for students to move from vocational track to academic university track and vice-versa, and providing incentives to attract qualified professors and students (Stewart, 2015).

According to Kwon (2009), there are three approaches to measure human capital. The first approach is output-based and relies on school enrollment rates, schooling attainments, adult literacy, average years of schooling and indicators akin to them. The second approach is cost-based and uses the cost paid for acquiring knowledge. The third approach is income-based and depends on the benefits reaped by individuals after investing in education and training. The first approach deals with aggregate measures of human capital, while the second and the third ones works at the individual level.

In this context, total labor force can be used as an aggregate measures of human capital. Jameel and Naeem (2016) used total labor force and other indicators as proxies for human capital in panel estimates. They found that total labor force showed a positive and significant effect on economic growth in all analyses. Sankay et al. (2010) also made use of total labor force as one of the measures of human capital and it presented a significant impact on economic performance in the short-run. Furthermore, Butt and Hassan (2008) employed total labor force as a human capital proxy and it had a significant effect on economic growth in both the short-run and the long-run.

In line with this, employment data can also be used as human capital measures. Ahmed and Ridzuan (2013) used the number of employment as proxy for human capital. Awokuse and Christopoulos (2009) used manufacturing employment as proxy for labor. In this investigation, we use manufacturing employment as proxy for human capital.

2.3 Economic structure and human capital at the micro-regional level

According to Hidalgo (2009) and Hidalgo and Hausmann (2009), an economy that presents a large set of capabilities can produce a diversified and non-ubiquitous mix of goods, which is associated with income growth. These capabilities come from certain productive factors such as: human and physical capital, labor, land, institutions and infrastructure. However, we focus on the relation between human capital and economic structure once human capital benefits innovation building and innovation use (Benhabib and Spiegel, 1994).

Income is related to economic structure, which in turn depends on human capital. However, how does this relation happens at the micro-regional level? As stated by Andersson and Johansson (2010), the accessibility of human capital is what matters for understanding regional economic structure in Sweden. They make a positive association between human capital availability and exports average unit prices. Then, the more available human capital is, the higher exports average unit prices are, which indicates quality upgrading in exports when human capital stock increases.

Andersson and Johansson (2010) also associate positively human capital with the extensive margins of exports. Increasing exports via extensive margin stands for a wider set of either exported goods, exporting firms or trading partners. Hence, the larger the stock of human capital is, the more diversified exports are. Additionally, Hummels and Klenow (2005) suggested the level of diversity is the major export growth channel.

Teixeira and Queirós (2016) used data on OECD countries and Mediterranean and Eastern Europe economies to analyze the relation between human capital, economic structure and economic growth. They concluded human capital and economic structure matter for income growth as well as their interaction. Additionally, if economic structure cannot employ the high-skilled workers, economic growth tends to be weak.

Čadil et al. (2014) used data on European regions to analyze the effect of human capital on economic growth according to the regional economic structure. They concluded there is no clear effect of human capital on economic performance.

For Brazilian economy, Bandeira Morais et al. (2021) analyzed economic structure and income distribution at the state level. They concluded economic structure plays a relevant role in explaining income distribution. Furthermore, Lima and Silveira Neto (2016) used data on Brazilian micro-regions and concluded human capital is important in understanding income growth.

Analysing the relationship between human capital and economic structure at the micro-regional level can bring up relevant issues. That is, economic structure is directly influenced by human capital that is inside its own micro-region. It happens due to the spatially tightness of human capital to municipalities and micro-regions (Simon and Nardinelli, 2002). In this context, we realized human capital and economic structure are significantly correlated to each other ($r = 0.7227,\ p - value < 0.01$).

In a micro-region, human capital faces less constraints to move among municipalities than in a meso-region or in a state. Given this ability to move among municipalities in a micro-region, economic structure is influenced by the availability of human capital in the micro-region. Hence, the micro-regional spillover effect should be considered.

2.4 Economic structure and other variables

In addition, even among the factors associated with economic structure, a direct relationship might be expected (Mayer, 2001; Li et al., 2015), e.g. higher stocks of physical capital boost human capital productivity. Thereby, human capital tends to increase in order to follow physical capital expansion, indicating a bi-causality relation between them. Similar relations may occur between human capital and institutions or human capital and technology.

Starting with the relation between economic growth and physical and human capital. Li et al. (2015) stated the economic role of physical capital declines as economy grows. In spite of that, human capital keeps its contribution to economic growth when development takes place. Further, Pablo-Romero and Gómez-Calero (2013) concluded the elasticity of private physical capital to economic growth declines as its stock increases, while the elasticity of human capital to growth increases when its endowments rises.

Another possible association is between natural resources, economic growth and human capital or institutions. Zallé (2019) affirmed human capital and institutions determine economic growth. They also argued natural resource abundance may be a curse if an economy does not invest in human capital as well as in institutional quality. Moreover, Amiri et al. (2019) stated there is a negative relation between natural resources and economic growth in economies where the institutional quality is low. On the other hand, when a country presents good institutions, natural resources show positive effects on growth. Hence, the natural resource curse only takes place where there are poor institutions.

Drawing attention to technology and human capital, Mayer (2001) stated government should invest in both human capital and technology adoption because they influence economic growth positively. However, investing only in human capital reduces the returns of education, while increasing only technology makes income inequality to grow. Furthermore, Bilbao-Osorio and Rodríguez-Pose (2004) argued a low level of human capital might influence the relation between R&D and innovation. That is, where human capital is low, R&D expenditures may not cause innovation.

In addition, Marvel and Lumpkin (2007) affirmed both general and specific human capital play fundamental roles in explaining radical innovation. This kind of innovation is the one that increases the possibilities of economic growth. They also stated formal education has an important positive association with radical innovation.

Turning to the relationship between institutions, human capital and economic growth, Faria et al. (2016) affirmed institutions cause economic growth. However, it is investment in human capital that increases institutional quality, which in turn leads to higher income. Moreover, Acemoglu et al. (2014) argued institutions are the determinants of growth and human capital is linking them.

In addition, Dias and Tebaldi (2012) affirmed that only structural institutions matter to long-run economic performance. According to them, the first institutions set in an economy stimulates or discourages investment in education, which influences human capital accumulation and then economic growth. In a second moment, the growth of human capital affects structural institutions.

Among the mentioned factors, human capital and institutions seem to play the most important factors associated with economic structure and growth. Given the effect of human capital and institutions, both would be used in explaining economic structure. However, there is a lack of data on institutions at the regional level (Acemoglu et al., 2014). That lack complicates the use of institutions in this kind of analysis and favor the use of human capital. Furthermore, institutional quality influences the long-term growth (Dias and Tebaldi, 2012), which is not the core of this investigation.

In this context, the omission of institutions would be surpassed by using an exogenous variation in human capital. This exogenous variation in human capital would show the effect of human capital on economic structure. Moreover, Sianesi and Reenen (2003) stated there is a need for studies of exogenous change in human capital.

The use of exogenous variation in a variable would be the proper way to capture its effect on another variable when other important variables are omitted. An exogenous variation might also deal with bi-causality issues. Thereby, exogenous variation in human capital should be used as an instrument to address the possibility of endogeneity coming from the omission of institutions as well as the bi-causality between human capital and economic structure.

3 Methodology

In methodological terms, comparing human capital and economic structure without considering the possibility of omitted variables or bi-causality between human capital and economic structure would yield inconsistent estimates. In the first case, omitted variables, such as institutions or geographical issues, would influence both human capital and economic structure simultaneously. That is, good institutions improve human capital as well as economic structure, putting aside the possibility of an effect of the former on the latter. Another alternative is that the omitted variables alter the effect of human capital on economic structure. It would happen if human capital and institutions affect economic structure but the former is considered and the latter is not, mistaking their effects. In the second case, there is a possibility of economic structure to influence human capital first or to present a bi-causality relation with it. Hence, it would be difficult to establish the causal effect of one variable on another.

The ideal experiment to estimate the effect of human capital on economic structure would be to improve human capital randomly across micro-regions. By doing so, we assume micro-regions are on average similar in observable and non-observable characteristics. Then, a comparison of economic structure between the micro-regions that had their human capital improved and the ones that did not would show the effect of the latter on the former. However, we do not have such experiments.

Economic structure may be explained by human capital and a group of other variables. However, certain variables are omitted and influence the analysis, institutions is one of them. The omission of institutions from the regression overestimates the effect of human capital on economic structure. That is, human capital would exhibit a larger effect on structure because institutions are not taken into consideration.

In the context of omitted variables, a manner of capturing the effect of human capital on economic structure would be an exogenous variation in the former. An exogenous variation in human capital would show its direct effect on economic structure because the other variables, including the omitted ones, do not change when an exogenous variation happens. So, the identification strategy uses a natural experiment as an exogenous variation in human capital, bypassing the omitted variables issue.

3.1 Identification strategy

The identification strategy in this study is to exploit a variation in human capital that is exogenous to its own micro-region. If an exogenous variation happens in human capital, a change in economic structure is expected to take place. This relation does not depend on the omitted variables but solely on the direct effect of human capital on economic structure. Hence, the use of an exogenous variation leads us to the instrumental variable method, which in turn is the adequate manner to capture the effect of human capital on economic structure.

The instrument is the expansion in the Brazilian federal network of technological and professional education. As expansion, we mean the establishment of 491 new IF units, going from 155 units in 2005 to 646 in 2021 and reaching all the states in Brazil. In 2005 only 19% of the micro-regions had at least one IF unit, while in 2021 that number went to 70% of the micro-regions, which increased the quantity of places offered in IFs[1]. We believe such expansion would alter the stock of human capital in a micro-region because investment in technical or vocational education improves the workforce skills (Ismail and Abiddin, 2014). Moreover, Hanushek et al. (2017) also affirmed vocational education favors the entry into the labor market.

In addition, Arriagada et al. (1992) suggested vocational schooling in Brazil has better effects on labor market than expected. According to them, completing the technical or vocational education provides higher earnings when people are employed in occupations linked to their field of study. However, when this distinction between occupations and related field of study is not taken into account, as in Tannen (1991), vocational schooling seems to make no differences on its students' earnings.

Thus, the only channel IFs influence economic structure is through its causal effect on human capital. There is a correlation between IFs and economic structure and what is behind this correlation is the causal effect of IFs on human capital. Hence, IFs do not cause economic structure directly. Given that, this paper takes advantage of the increase in places in IFs to evaluate the effect of human capital on economic structure.

Two assumptions are needed for a good instrument. The first assumption is that the instrument must have a direct effect on the endogenous variable. The second assumption is the exclusion restriction, which is divided into two parts: the first part is that the instrument has no influence on the dependent variable, except via the endogenous variable channel; the second part is that the instrument is randomly assigned.

The second assumption has two parts. The first part is that places in IFs are not direct related to economic structure. According to Toner (2011), when the quality of labour is improved by education and training, the complementary between human capital and physical capital grows. That is, it is human capital that influences the productivity and marginal returns of physical capital and all other output factors.

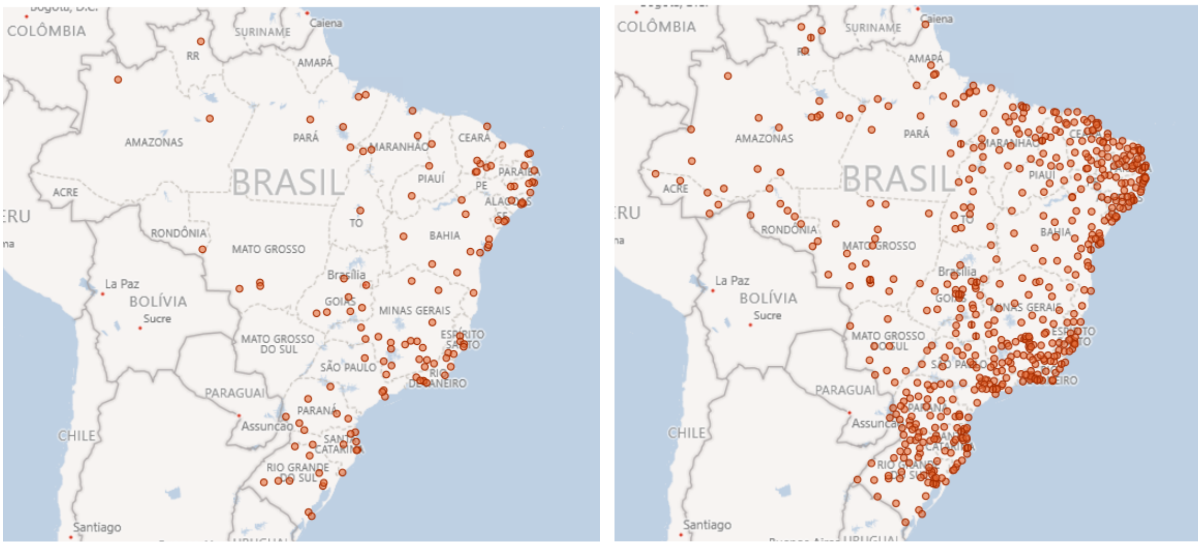
Furthermore, IFs offers technical and technological courses, which are intended to increase the possibilities of local people. To an IF influence directly the micro-regional economic structure, it should produce and export final goods instead of training and improving local people's capabilities. Even though IF laboratories are able to produce a small amount of certain products, these products are not planned to be treated as market goods (Corrêa et al., 2017). Thus, increasing places in IFs is a way of affecting human capital but not economic structure directly.

[1] We consider that the quantity of places in a micro-region is constant unless a new IF campus is established in the micro-region. Although constant places in IFs might not be real for a few micro-regions, a case study for each IF campus should be done if constant places are not assumed.

The second part of the second assumption is that places in IFs are unrelated to non-observable variables or to the error term. Then, we argue the new IF units was conditionally random and below are the three aspects underpinning that conviction.

The first aspect is that funding sources for the IFs are federal, decreasing the probability of a correlation between regional income and this schooling investment. The second aspect is that a new IF is beyond both the influence of the micro-regional government on the federal government goals and the micro-regional characteristics, such as agriculture, industry, public or non-public services in output. And, third, the expansion of IF network was not solely located in a state or country region but happens throughout Brazil. Figure 2 displays the distribution of IFs in 2005 and 2021.

Figure 2: The Brazilian federal network of technological and professional education



(a) IF Units in 2005

(b) IF Units in 2021

Note: Each red dot indicates a municipality where there is at least one unit of the Brazilian federal network of technological and professional education.
Source: Brazilian Ministry of Education.

As displayed in the Figure 2, the IFs are scattered all over the country. Hence, we assume the rise in IFs is not related to non-observable micro-regional characteristics, which means the instrument is at least conditionally random at the micro-regional level.

Besides the fact that new IFs were established randomly, we also assume that the rise in IFs is not directly related to economic structure. Although the increase in IFs displays a positive correlation with economic structure in micro-regions, it only happens because human capital is linking them.

We use a panel with 430 micro-regions from 2003 to 2015 and the dependent variable is economic structure. The estimator used is the Two Stage Least Squares (2SLS), which has the two following equations:

$$HC_{it} = \delta_i + \iota_t + \gamma_1 IF_{it-1} + \gamma_2 PH_{it} + \gamma_3 TO_{it} + \sum_{a=1}^{a=3} \gamma_{4a} Eco.Sec_{ait} + \mu_{it} \quad (3)$$

$$Eco.Stru_{it} = \delta_i + \iota_t + \rho_1 \widehat{HC_{it}} + \rho_2 PC_{it} + \rho_3 TO_{it} + \sum_{a=1}^{a=3} \rho_{4a} Eco.Sec_{ait} + \vartheta_{it} \quad (4)$$

Where i stands for the micro-region, t for the year and a for the economic sectors: agriculture (a=1), industry (a=2) and government services (a=3). $Eco.Stru$ is economic structure; IF is the quantity of places in IFs in the micro-region; HC is human capital; PC is physical capital; TO is a measure of trade openness; $Eco.Sec$ is the share of each economic sector; δ is the intercept of each micro-region; μ is the error term of the first stage; and ϑ is the error term of the structural equation .

The proxy for economic structure is the economic complexity index (ECI). The concept of economic complexity is based on productive knowledge an economy holds (Hidalgo et al., 2007; Hidalgo, 2009; Hidalgo and Hausmann, 2009). In theoretical terms, economic complexity brings a different glance at income growth process. However, as all economic measures, complexity has certain limitations and Salles et al. (2018) point out three of them. The first limitation is not using data on services; the second limitation is analyzing only the supply side of economy; and the third limitation is ignoring the output that is not exported. In spite of that, Salles et al. (2018) considered the ECI the proper approach to analyze economic structure and export sophistication.

In addition, ECI was initially developed for analyzing countries. Taking ECI at the subnational level may bring some issues to analysis, one of them is the difference between international trade data and intra-national trade data. In order to cope with it, Freitas and Paiva (2015) proposed the inclusion of two terms in the ECI calculation[2]. These two terms are: the share of a micro-region's exports of a product to the country's total exports of that product; and the micro-region's RCA in exporting that product. By doing so, the ECI is taking into account the micro-region's share of a goood in country's total exports and also the relevance of a good in the micro-region's export basket.

Although the adjustment made by Freitas and Paiva (2015), the ECI available at the subnational level for Brazil does not consider the relation between micro-regions inside the country. To do so, detailed trade data across micro-regions should be used. In this strand, Reynolds et al. (2018) used input-output tables to calculate the ECI for Australian states and territories, while Gao and Zhou (2018) estimated the ECI for Chinese provinces using data at the firm level. Balland and Rigby (2017) used patent records to measure the complexity of knowledge at the city level in the United States.

The measure of human capital is total labor force working on manufacturing industry. The proxy for physical capital is the micro-regional output share spent on gross fixed capital formation weighted by micro-region's total establishments[3].

A measure is constructed to access the trade openness level of an economy. It is based on the sum of imports and exports as a percentage of output, and micro-region's population. The sum of imports and exports as a percentage of output is regressed on the micro-region's population and the error term is separated. The estimate's residual is about all the other variables related to trade openness, except the micro-region's export, imports and population. Afterward, the residual of the mentioned estimate is multiplied by a measure of trade terms, which is a ratio of an export price index to an import price index. Thus, the trade openness variable is controlled for differences in international prices, population, output, imports and exports[4].

Economic sector is compounded of four variables. These variables are the gross value-added that comes from each of the economic sector (agriculture; industry; non-government services; and government services) as a share of micro-regional output.

[2] This study used the formula proposed by Freitas and Paiva (2015).
[3] Carmo et al. (2017) used a similar a approach to infer physical capital at the micro-regional level.
[4] Barro (2003) used a similar approach to capture the impact of trade openness on economic growth.

3.2 Data source

The ECI values lies between -∞ and ∞ with 0 average and 1 as standard deviation. Data used to elaborate the ECI come from the Brazilian Ministry of Development, Industry and Trade (MDIC). Data on economic complexity goes from 2002 to 2017 and is made available by *Dataviva*[5] site. The site employs the same methodology Simoes and Hidalgo (2011) used to calculate the ECI. Complexity data needs no aggregation because it is available at the micro-regional level.

The labor force working on manufacturing industry is provided by the Annual Social Information Report (RAIS). RAIS is an annual administrative record of Brazilian formal labor market. It presents data on jobs, wages, industries, among others. These data are divided according to the National Classification of Economic Activities (CNAE). Brazilian Ministry of Labor and Employment (MTE) collects this information from all formal businesses and *Dataviva* makes it available.

Data on the Brazilian federal network of technological and professional education are made available by Brazilian Ministry of Education (MEC). Brazilian Institute of Geography and Statistics (IBGE) provides data on gross domestic product, population and the value-added of each economic sector. All these data needed aggregation, once they were not available at the micro-regional level. The Table I presents information on variables, proxies and sources of data.

Table I: Data source and explanation for micro-regions

Variable	Proxy	Uses data on	Source
Economic Structure	Economic Complexity Index	World's, country's and micro-region's exports	Dataviva
Human Capital	Total labor force working on manufacturing industry	Jobs, wages, industries and the classification of economic activities	MTE
Instrument	Places in IFs	Federal network of technological and professional education	MEC
Physical Capital	Micro-regional output share of gross fixed capital formation adjusted by establishments	Gross fixed capital formation and micro-regional data on establishments and output	IBGE and MTE
Trade Openness	A calculated measure of trade openness	Terms of trade and micro-regional data on exports, imports and output	MDIC, IBGE and FUNCEX
Economic Sector	Share of each economic sector in value-added	Value-added by agriculture, industry and non-government services	IBGE

Note: MTE means Brazilian Ministry of Labor and Employment; MEC means Brazilian Ministry of Education; IBGE means Brazilian Institute of Geography and Statistics; MDIC means Brazilian Ministry of Development, Industry and Trade; and FUNCEX means Foundation Center for Foreign Trade Studies.
Source: Elaborated by author.

Table II and III show the summary statistics of two groups of micro-regions.The first group is the micro-regions that have no IF units, while the second is of micro-regions that have at least one IF unit. From Tables II and III, we can highlight the micro-regions that have at least one IF unit present in average better economic structure, human capital, trade openness and economic sectors when compared to micro-regions with no IF units.

4 Results and Discussion

In order to try to satisfy the first assumption of a 2SLS estimator, we have run a regression of the first stage. The results of the first stage were that places in IFs have a positive and significant effect on human capital. Then, the first assumption for a good instrument is fulfilled and the instrument is relevant. Moreover, Table IV shows the

[5] *Dataviva* is an open search platform promoted by the Government of the State of Minas Gerais, the State of Minas Gerais foundation for research funding and support (FAPEMIG), Minas Gerais Investment and Trade Promotion Agency (INDI) and Datawheel.

Table II: Summary statistics for micro-regions with no IF units between 2002 and 2015

	Observation	Mean	Std.Dev.	Minimum	Maximum
Economic structure	3368	-0.07052	2.3009	-17.280	30.405
Human capital	3299	9498.5	17972.4	1	239686
Places in IFs	3591	0	0	0	0
Physical capital	3089	0.0005866	0.0002778	0.00003122	0.002016
Trade Openness	3028	-3312.3	60921.6	-32481.6	1190825
Agriculture	3368	317266.3	298591.3	3475	2615894
Industry	3368	979204.9	2285281.0	2832	33668760
Government services	3368	500904.5	636527.7	30733	7928515

Note: IFs means the Brazilian federal network of technological and professional education.

Source: Dataviva; MTE; MEC; IBGE; MDIC and FUNCEX.

Table III: Summary statistics for micro-regions with one or more IF units between 2002 and 2015

	Observation	Mean	Std.Dev.	Minimum	Maximum
Economic structure	2875	0.1277	4.4401	-19.140	55.140
Human capital	3947	14165.1	49362.3	0	759021
Places in IFs	2318	1003.1	1558.8	40	16603
Physical capital	2157	0.0004829	0.0003785	0.000001894	0.002592
Trade Openness	2724	4129.2	67362.0	-32489.0	1032020.5
Agriculture	2875	490826.4	674753.8	4670	8283140
Industry	2875	6422683.5	27632093.8	3184	440834688
Government services	2875	7020158.6	50392437.4	26990	980025856

Note: IFs means the Brazilian federal network of technological and professional education.

Source: Dataviva; MTE; MEC; IBGE; MDIC and FUNCEX.

results of the structural form and three other estimators are presented to be compared with the 2SLS estimator.

Hereafter, we consider the significance level at 0.10. Only human capital presented significant effects on economic structure, while physical capital, trade openness and the economic sectors of agriculture, industry, non-government services and government services showed no significance at all. We believe the differences in factor endowment across micro-regions explain the absence of an effect of physical capital, trade openness and economic sectors on economic structure. Other explanation is that these variables influence economic structure through human capital.

The coefficients are in standard deviation terms. A one-standard-deviation increase in human capital is associated with a 1.057 standard-deviation increase in the economic structure. The micro-regions presented different one-standard-deviation increasing paces in human capital.

Among the 17 micro-regions that presented a one-standard-deviation increase in human capital from 2003 to 2014, the fastest ones were the micro-regions of São Paulo-SP, Belo Horizonte-MG, Campinas-SP and Rio de Janeiro-RJ, while the slowest ones were the micro-regions of Caxias do Sul-RS, Blumenau-SC and Goiânia-GO. The increase of one standard-deviation in human capital occurred in one year in the

Table IV: Economic structure regression

	OLS	Panel (A)	Panel (B)	2SLS
Human capital	0.75286***	0.28389*	0.33871**	1.05667**
	(0.0000122)	(0.0000113)	(0.0000119)	(0.0000335)
Physical capital	0.09158***	0.01697**	-0.00933	-0.04100
	(354.6)	(96.95)	(134.9)	(318.5)
Trade Openness	0.00511	0.01033	0.00924	-0.00455
	(0.00000138)	(0.000000842)	(0.000000819)	(0.000000752)
Agriculture	-0.03638	0.04470***	0.03838**	0.04390
	(0.939)	(0.419)	(0.519)	(1.063)
Industry	0.01735	0.04551	0.05302	0.02805
	(8.088)	(3.952)	(4.032)	(3.256)
Government services	-0.03603	-1.91760***	-1.91492***	-1.59667***
	(4.204)	(13.55)	(13.44)	(24.61)
Observation	4765	4765	4765	4265
F-statistic	9.1406	16.8994	19.8250	51.5141
P-value	0.0000	0.0000	0.0000	0.0000
Micro-region FE	No	Yes	Yes	Yes
Year FE	No	No	Yes	Yes

Note: Standardized beta coefficients; standard errors in parentheses and clustered at the micro-regional level; standard errors are also clustered at the state level in the 2SLS estimate; * $p < .1$, ** $p < .05$, *** $p < .01$.
Source: Elaborated by author.

micro-region of São Paulo-SP, three years in the micro-regions of Belo Horizonte-MG, Campinas-SP and Rio de Janeiro-RJ and in eleven years in the micro-region of Caxias do Sul-RS, Blumenau-SC and Goiânia-GO. Furthermore, 541 micro-regions did not present a one-standard-deviation increase in human capital from 2003 to 2014.

In order to check the robustness of the results, we tested alternative proxies for the right-hand variables of Equation 4. The first alternative measure is total labor force working in the micro-region as a proxy for human capital instead of the labor force working in manufacturing industry. Even though that measure is not specific, using the total labor force as the measure of human capital yielded similar results.

Drawing attention to trade openness, two measures might be utilized instead of the proxy used. The first measure is the sum of imports and exports as a percentage of output. The second measure is the effective diversity of exports destinations, which depends on the quantity of locations importing a micro-region's products as well as on the share of each importing location. Despite the differences in calculations, the use of each of the proxies for trade openness produced similar results when comparing to the constructed measure based on imports, exports, output, population and trade terms.

Regarding physical capital, we used two alternative measures for this variable. The first proxy was lagged gross domestic product and the second one was the quantity of establishments in the micro-region. Both alternative measures turned the relation between human capital and economic structure insignificant.

5 Concluding Remarks

This study contributes to the debate on the relevance of human capital on the micro-regional economic structure. Since economic structure is revealed by exports sophistication and indicates future income growth, this investigation concentrated on the relation between human capital and export sophistication.

The economic complexity index was the proxy for export sophistication. This measure is based on the ubiquity and diversity levels of exports, the share of international trade, the connections between goods, the relevance of the micro-region in the country's total exports and the importance of the product in the micro-regional export basket. The estimate is for the period of 2003 to 2015 with a sample of 430 micro-regions.

According to results, human capital is a central key in explaining economic structure in micro-regions where the quantity of places increased. In these micro-regions, the quantity of places in IFs was an adequate instrument for micro-regional human capital, setting a positive and significant effect of places in IFs on human capital. Furthermore, human capital presented a positive effect on economic structure.

Our findings suggest a rise in places in IFs, which are investment in human capital, lead to economic structure upgrading. Thus, policies such as the expansion of Brazilian federal network of technological and professional education should be promoted.

One limitation to deal with is data availability, especially in terms of human capital observations. Another limitation is only taking data on formal labor market. Moreover, it is possible that the quantity of observation is influencing the estimate efficiency.

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