An Analysis of Engineering Education impact on Brazil´s Micro Regions

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Abstract

Engineering Education has been, as a part of the HRST, a significant factor according the OCDE in correlating to GDP. Previous studies demonstrate that the shortage of engineers in a country as vast as Brazil need to be understood in a microregional scenario and shows that the microregions with HEI´s are often the only ones that can leverage their development indexes (HDI_E and HDI_R). Not only are the differences in the country great on a region by region approach, but spillovers and HEI´s products need to meet local demands. Based on the bibliographical review and raw government and official data analysis this study concludes that there is a significant impact factor on a city ability to leverage its development if a HEI is placed and the spillover factor for the remaining cities of the same microregion is also present. This study also concludes that the quality of an HEI is also important to assess the amount of leverage it will be able to achieve.

Keywords
Engineering Education, Microregional Development, Shortage of Engineers, Human Development Index

1. Introduction

Since the Organization for Economic Co-operation and Development (OECD) began publishing the Going for Growth reports in 2005, there´s been a significant amount of research to understand the impacts of Human Resources in Science and Technology (HRST) influence in a country´s Gross Domestic Product (GDP). All careers of Engineering, since they are a significant part of HRST, has had a special focus not only from the Engineering Education community but also from the general public that understand the importance of Engineers in developing the society and creating innovation. Since the GDP focus only on economic output, another largely used index that takes in consideration a more complete set of variable is the Human Development Index (HID). It presents as a better comparison as it takes into account not only revenue but also education and life expectancy.

This article is a continuation of a study presented by the authors in other congresses and journals. This paper will focus primarily on the impact of the presence of HEI´s and the quality of the institutions as a toll to leverage the microregional development.

This paper will have the following the structure: bibliographical review focused on the Shortage (or Lack) of engineers, the leveraging of GDP, the Regional factors and impacts of Engineering High Education Institutions (HEI) and the university products and spillovers. After that the article will focus on the method of separation of HEI´s by Preliminary Course Concept - CPC (*Conceito Preliminar de Curso*) and the calculation of both the Human

Development Index (HDI) – Income (HDI_I) and Education (HDI_E)[1] the selection of cities and microregions and the averaging of results calculation followed by the discussion. Lastly the conclusions are demonstrated.

1.1. Shortage of Engineers

The topic of shortage of Engineers, both in Brazil and in other countries, has had several papers concerned about it. The research on the topic has been taken place for several years and examples can be found in Cappelli (2015), Kahn (2015), Butz et al. (2003), Green et al. (1998) among others. In Brazil the topic has been also debated by authors such as Lins et al. (2014), Salerno et al. (2014), Nascimento (2011). Market demands have been taken into consideration by Souza and Domingues (2014) and a concern about the fact that most engineers are not in their typical professions was demonstrated by Maciente and Araújo (2011).

The articles and research are prominently focused on the output of engineers and the analysis is targeted mostly on the economic aspects such as salary, ability to fill positions and others. Cappelli (2015) brings an interesting idea that the shortage, if it exits, can be interpreted as other factors that do not involve necessarily the graduation and curriculum but the new demands for high end positions – that have higher demands and fewer professional available - and difficulty in the hiring procedures.

In Brazil the studies are focused on the parameters laid down by Butz et al. (2003) that adapts the economic factors to the HEI scenario. The quality of HEI´s is mentioned by researches, however there is very few meaningful comments about their importance and fewer data about it. The placement of the HEI was discussed by Caldana and Terra da Silva (2017) in which the factors of HDI_I and HDI_E are cross-referenced with the location of HEI´s, and a conclusion is reached that the presence of HEI is directly linked to a better development in the microregions. It is important to disclaim that a cause-effect type of scenario can´t be determined as there are multiple factors influencing the development of a region.

1.2. Leveraging GDP

As mentioned, the presence of HRST does have not a simple cause-effect relationship to development. Lins et al. (2014) displays a country-by-country correlation between HRST presence and GDP per capita. The authors present data that would indicate an estimated value of GDP for HRST available in the country. This average line is what should be the expected value of GDP, but there are cases that varies significantly from the average. Such cases are both positive and negative.

In the positive cases, it shows that some countries can leverage their GDP per capita. Cases are seen in countries like Japan, USA and Norway. These countries can, in a sense, take a better advantage of their local HRST resources and by doing so their economy factors – represented by GDP – are enhanced. On the other side, there are cases that follow below the correlation line and displays the inability to explore properly the HRST resources. Countries like Brazil, Turkey and Poland are an example of this. The explanations for the fact that the aforementioned countries are unable to leverage their GDP are multiple and can vary from quality of education, lack of innovation, poor economic scenario that does not create enough opportunities, etc.

This clearly indicates that the amount of HRST per se is insufficient to understand the countries global GDP and other factors must be taken into consideration, such as regional presence and quality of degrees. (Caldana and Terra da Silva, 2017). One important factor discussed by Kakiuthi et al. (2014) is the preparation of high school (and even fundamental) students to enter on science related careers.

1.3. Regional Factors and Impact of HEI

In a country as vast as Brazil the presence of HEI´s evenly spread in the territory could be a possible factor to leverage HDI and equally develop regions. The discussion of regional development is taken by Quandt (1997) and examples of curriculum specific designed for local needs can be seen in Lansu et al. (2013).

[1] The Life expectancy portion (HDI_L) is not used in this study as it needs special tables assessment taht are not available for the selection of cities made.

The study of the impact of HEI´s in the microregions are showed by Caldana and Terra da Silva (2017). The summary is showed in Table 1 below. The table displays that the presence of HEI´s in a microregion will yield better results when compared to state values. The comparison to state values is necessary as the development of the country is irregular and the country´s reference does not represent necessarily the region´s scenario. The results from the research also shows that the presence of the capital deviates the final results as the economic and general development in the capital city will be greater than the rest of the state for the presence of the government and all the necessary branches and structure that it carries with it. It also displays the difficulty of regions without HEI to achieve good development indexes when compared to the state values. Since the values are not always true and there are some microregions that either do not leverage when having HEI´s and some that do despite that the finding do support the non cause-effect theory.

The table uses the following categories:

- MRW+ : The number of micro-regions with at least one HEI which has a better HDI index than the state value
- MRW- : The number of micro-regions with at least one HEI which has a worse HDI index than the state value
- MRN+ : The number of micro-regions without HEI which has a better HDI index than the state value
- MRN- : The number of micro-regions without HEI which has a worse HDI index than the state value

Table 1 – Micro-Regional HDI_Education and HDI_Income results

Macro Region	**State**	**HDI_EDUCATION**				**HDI_INCOME**			
		MRW+	**MRW-**	**MRN+**	**MRN-**	**MRW+**	**MRW-**	**MRN+**	**MRN-**
Central-West	MS	1	0	1	9	1	0	1	9
	MT	3	3	3	13	3	3	3	13
	GO	2	2	0	14	3	1	0	14
	DF	-	-	-	-	-	-	-	-
Northeast	MA	2	0	0	19	2	0	2	17
	PI	1	1	1	12	1	1	0	14
	CE	2	1	0	32	1	2	0	30
	RN	2	0	0	17	2	0	0	17
	PB	3	1	0	19	2	2	0	19
	PE	1	1	3	14	1	1	1	16
	AL	1	0	0	12	1	0	0	12
	SE	1	0	0	12	1	0	0	12
	BA	4	5	1	22	3	6	0	23
North	RO	1	1	1	5	1	1	1	5
	AC	1	0	0	4	1	0	0	4
	AM	1	1	0	11	1	1	0	11
	RR	1	0	0	3	1	0	0	3
	PA	3	2	2	15	3	2	2	15
	AP	1	0	0	3	1	0	0	3
	TO	2	0	2	4	2	0	2	4
Southeast	MG	19	11	4	32	8	22	1	35
	ES	1	4	0	8	1	4	0	8
	RJ	3	8	0	7	2	9	0	7
	SP	19	15	0	29	4	30	0	29
South	PR	7	8	1	23	3	12	0	24
	SC	6	8	0	6	4	10	0	6
	RS	10	9	3	13	4	15	1	15

Source: (Caldana and Terra da Silva, 2017)

1.4. University Products and Spillovers

It is important to understand and HEI as not only a factory of Engineers. The analysis and use of CPC concept comes to offset that idea and also to take into consideration other important factors of HEI production. Lendel (2010) creates a very interesting layout of what the products and impacts an HEI can achieve. This spillover effect is studied by Drucker (2016) that points to a 97 kilometers (60 miles) area in which the HEI will have a significant positive impact. The radius described by Drucker enforces the selection of microregions for the study and the city-by-city separation.

Other relevant factors of HEI´s are also pointed out in the researches of Litzinger et al. (2011) – that points to the development of expertise – and Sgobbi and Cainarca (2015) – that analyses the impact on high-paying jobs in Europe.

2. Methodology

As state before, this is a continuation of the study already presented and as such the methodology presented for item 2.1 will be a brief version. This study uses microregions as a definition of a group of cities as defined by IBGE (2016) and Macro Regions as the groups of states.

2.1. CPC, HDI_E and HDI_R

As discussed by Caldana and Terra da Silva (2017), to understand and grade HEI in a complete method of evaluation it is necessary to take into account the Preliminary Course Concept - CPC (*Conceito Preliminar de Curso*). The CPC grade aggregates other variables than simply number and is more complete. The calculation criteria and the detailed document is available from the National Institute of Studies and Research - INEP (Instituto Nacional de Estudos e Pesquisas) (INEP, 2016). The CPC formula from 2011 used the following indexes:

$$CPC_j = (0{,}35 * NIDD_j) + (0{,}20 * NC_j) + (0{,}15 * ND_j) + (0{,}075 * NM_j) + (0{,}075 * NR_j) + (0{,}075 * NO_j) + (0{,}05 * NF_j) + (0{,}025 * NA_j)$$

Where:

- CPCj is the calculated value of the index for each HEI
- NIDDj is the index that reflects the “advance” in knowledge by the students (it measures the difference between the average of ENDAE scores of freshmen and graduates at the institution)
- NCj is the ENADE score
- NDj is the proportion of teachers with PhD´s in the HEI
- NMj is the proportion of teachers with Masters in the HEI
- NRj is the work regime of the teachers (better grades are given to exclusive professionals)
- NOj is the grade from the Pedagogical assessment
- NFj is the facilities grade (laboratories, classrooms, etc.)
- NAj is the grade from the opportunities given by the HEI for continuous study

To establish a mean to consolidate the universities 5 categories were created. High Quality HEI´s are considered ate categories CPC4 and CPC5.

- CPC1 has HEI´s with grades from 0,01 to 1 or with SC grade
- CPC2 has HEI´s with grades from 1,01 to 2
- CPC3 has HEI´s with grades from 2,01 to 3
- CPC4 has HEI´s with grades from 3,01 to 4
- CPC5 has HEI´s with grades from 4,01 to 5

To assess the impact of the HEI´s the Human Development Index (HDI) is selected, as it is largely utilized in comparison between countries and has no direct impact from higher education (the education portion uses as far as high school level), being able to represent the effects in a broad spectrum and in long-term influences. This study focuses on both Education (HDI_E) and Income (HDI_I) aspects of the index. (Caldana and Terra da Silva, 2017)

The formulas for each are:

$$HDI\_Education = \sqrt[3]{P_{18+} * \left(\frac{P_{5-6} + P_{11-13} + P_{15-17} + P_{18-20}}{4} \right)^2}$$

Where:

- HDI_Education is the calculated value of the index for each selected group of cities
- P18+ is the percentage of the selected group of cities total population over 18 years with high school degrees
- P5-6 is the percentage of the selected group of cities total population between 5 and 6 years in school
- P11-13 is the percentage of the selected group of cities total population between 11 and 13 years in the final years of elementary school
- P15-17 is the percentage of the selected group of cities total population between 15 and 17 years with complete elementary school
- P18-20 is the percentage of the selected group of cities total population between 18 and 20 years with complete high school

$$HDI\_Income = \frac{\ln(RPCI) - \ln(MinI)}{\ln(MaxI) - \ln(MinI)}$$

Where:

- HDI_Income is the calculated value of the index for the selected group of cities
- RPCI is the per capita income of the selected group of cities
- MinI is the minimal per capita income, calculated from USD100 PPC. The value equals R$ 8,00
- MaxI is the greatest per capita income, calculated from the per capita income of the 10% more rich on the wealthier state of the country. This value is R$ 4.033,00.

2.2. Selection of Cities and Separation of Microregions

To understand the impact of HEI´s and to eliminate discrepancies created by the state´s capitol 5 groups of cities where created. The purpose is to classify each city as either having an HEI, being impacted by one or not having any proximity to an existing HEI. If the capital has an HEI it will not be reconsidered in the other categories as it would create a duplicity in data. This will also help to understand if the capital is the only city on the state with HEI´s (High quality or otherwise)

For each group of cities HDI_E and HDI_I indexes were calculated using the absolute values from each city using the formulas described in section 2.1.

The categories created for this study are:

- SC : State Capital – Includes only the capital of each state (all have at least one HEI)
- CH+ : Cities that have at least one high quality HEI (CPC4 or CPC5).
- CH- : Cities that have at least one HEI (CPC1, CPC2 or CPC3)
- CIH : Cities without HEI´s but in a microregion that have an HEI and are directly impacted by the proximity
- CNH : Cities without HEI´s and in a microregion without an HEI

2.3. Comparison Method

To eliminate the discrepancies and influences of the various regions and their different indexes, all comparisons on this study will take into consideration when analyzing values the only the "*percentage of improvement / decrease*" in the HDI_I and HDI_E indexes. By working with percentage values it enables to aggregate the percental variation to create a more complete view of the country and deals only with the leverage capability rather than absolute numbers. A simple comparison of percentage is made in all 5 categories listed on section 2.2 to the state reference because of the country´s disparity in regional development.

It is important to notice that some regions will not have all categories as the distribution of HEI´s in the country is not symmetrical. For those cases, the value was left open (and not 0) so it will not affect the final average. A zero value would indicate that the group of cities would have the same development and create a deviation on the avarege.

3. Results

To follow are the main results of the data analysis. The analysis took into consideration all data from the 2010 census (IBGE, 2014; PNUD et al, 2013) and 2011 CPC results (INEP, 2015) . The discussion is made on the comments below and the data that supports these findings are displayed on the sections 3.1 and 3.2 on the tables.

A complete breakdown of the number of cities in each state is displayed in Figures 1 and 2. Figure 1 displays on CH+ and CH- categories while Figure 2 displays CIH and CNH. The division was necessary as the absolute number of cities in CIH and CNH categories would make the visualization of CH+ and CH- unintelligible.

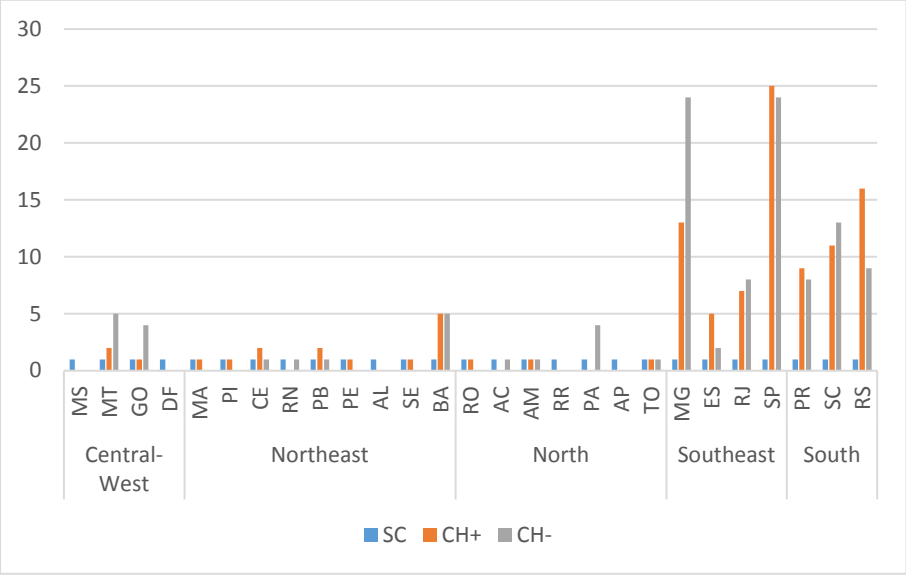

Figure 1 – City distribution for CH+ and CH-

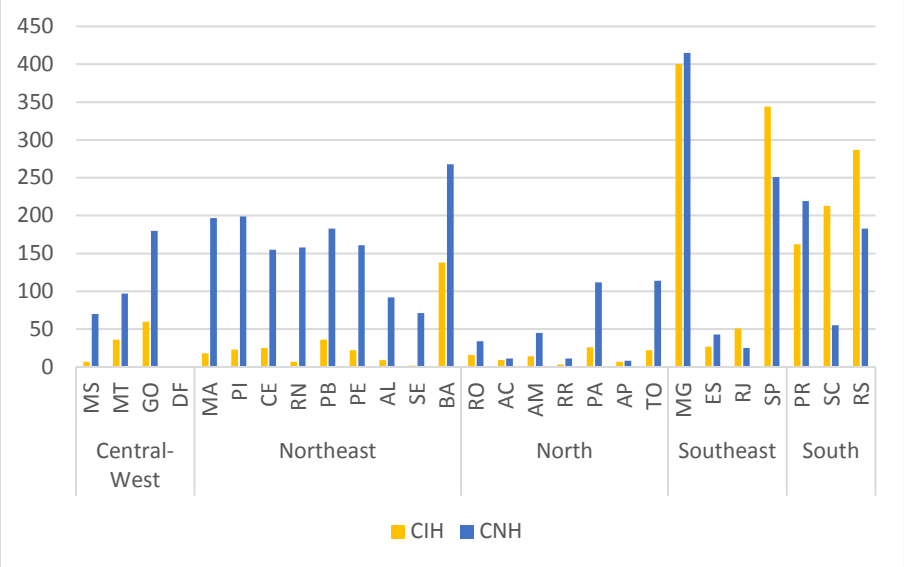

Figure 2 – City distribution for CIH and CNH

3.1. HDI_E Results

Results for the average of all regions education part of HDI are showed in Table 2. The individual state-by-state values are displayed on Table 3.

Table 2 –HDI_Education total results

HDI_E	SC	CH+	CH-	CIH	CNH
Country Average	**17,32%**	**5,97%**	**3,49%**	**-5,74%**	**-10,70%**

Table 3 –HDI_Education state-by-state results

Macro Region	State	State HDI	SC	CH+	CH-	CIH	CNH
Central-West	MS	0,630	15,11%			-13,53%	-6,99%
	MT	0,697	14,39%	3,98%	6,71%	-6,09%	-7,52%
	GO	0,646	14,48%	10,71%	0,57%	-4,64%	-5,97%
	DF	0,742					
Northeast	MA	0,562	33,89%	24,25%		11,27%	-11,33%
	PI	0,547	29,38%	2,80%		-13,40%	-11,04%
	CE	0,616	12,86%	6,62%	8,05%	-1,39%	-9,95%
	RN	0,597	16,28%		11,13%	12,26%	-11,98%
	PB	0,555	24,84%	17,61%	-16,94%	-2,41%	-12,87%
	PE	0,574	21,61%	-0,88%		6,46%	-10,84%
	AL	0,520	21,98%			-0,15%	-11,69%
	SE	0,560	26,38%	3,76%		2,86%	-14,02%
	BA	0,555	22,31%	10,88%	9,69%	-9,83%	-10,06%
North	RO	0,578	10,28%	6,69%		-12,87%	-3,08%
	AC	0,559	18,21%		4,06%	-18,75%	-21,99%
	AM	0,561	17,33%	-19,73%	-4,94%	-16,99%	-20,96%
	RR	0,628	12,71%			-33,62%	-19,56%
	PA	0,527	27,68%		13,19%	4,73%	-13,63%
	AP	0,629	5,41%			-2,66%	-16,06%
	TO	0,624	20,15%	13,14%	12,39%	-8,59%	-6,44%
Southeast	MG	0,637	15,54%	10,67%	7,31%	-6,66%	-10,11%
	ES	0,653	23,22%	3,38%	4,97%	-9,77%	-8,57%
	RJ	0,675	6,54%	1,65%	-4,73%	-5,58%	-7,92%
	SP	0,718	0,87%	5,13%	1,76%	-3,24%	-5,02%
South	PR	0,668	14,93%	4,98%	1,25%	-7,12%	-6,78%
	SC	0,697	14,76%	4,40%	2,45%	-5,59%	-7,59%
	RS	0,642	9,27%	3,31%	2,34%	-4,04%	-6,14%

Source: (INEP, 2015; PNUD et al, 2013)

3.2. HDI_R Results

Results for the average of all regions revenue part of HDI (HDI_R) are showed in Table 4. The individual state-by-state values are displayed on Table 5.

Table 4 –HDI_Revenue total results

HDI_E	SC	CH+	CH-	CIH	CNH
Country Average	**12,53%**	**2,02%**	**-1,89%**	**-6,65%**	**-8,89%**

Table 5 –HDI_Revenue state-by-state results

Macro Region	State	State HDI	SC	CH+	CH-	CIH	CNH
Central-West	MS	0,740	6,72%			-7,63%	-3,94%
	MT	0,773	9,23%	-1,15%	1,18%	-3,84%	-3,93%
	GO	0,742	11,01%	3,64%	0,58%	-4,36%	-6,00%
	DF	0,863					
Northeast	MA	0,612	21,12%	13,99%		0,95%	-9,62%
	PI	0,635	15,11%	4,65%		-11,09%	-8,43%
	CE	0,651	15,01%	-0,93%	-5,21%	-7,02%	-12,80%
	RN	0,678	13,15%		2,27%	5,77%	-11,69%
	PB	0,656	17,36%	6,78%	-10,57%	-2,78%	-12,01%
	PE	0,673	18,59%	1,26%		-1,36%	-10,73%
	AL	0,641	15,17%			-4,73%	-11,75%
	SE	0,672	16,69%	-7,14%		-7,09%	-12,63%
	BA	0,663	16,28%	1,92%	6,92%	-8,19%	-10,66%
North	RO	0,712	7,32%	2,28%		-7,25%	-3,28%
	AC	0,671	8,50%		-3,56%	-15,47%	-11,34%
	AM	0,677	9,05%	-8,20%	-8,73%	-15,95%	-17,72%
	RR	0,695	6,09%			-21,88%	-15,22%
	PA	0,646	16,10%		1,73%	-2,11%	-8,59%
	AP	0,694	4,20%			-7,33%	-8,82%
	TO	0,690	14,37%	6,60%	1,33%	-6,34%	-5,56%
Southeast	MG	0,730	15,24%	5,02%	0,20%	-5,74%	-7,71%
	ES	0,743	17,91%	0,68%	-2,01%	-7,72%	-6,43%
	RJ	0,782	7,44%	1,82%	-8,25%	-10,28%	-8,87%
	SP	0,789	6,83%	2,65%	-2,75%	-6,93%	-7,29%
South	PR	0,757	12,17%	1,30%	-2,23%	-5,90%	-6,38%
	SC	0,773	12,53%	1,82%	-0,17%	-3,68%	-4,62%
	RS	0,769	12,66%	1,39%	-2,87%	-5,04%	-5,22%

Source: (INEP, 2015)(PNUD et al., 2013)

4. Discussion

When the separation of the cities in categories was concluded it displayed that the macro regions of the Central-West, Northeast and North (which are the regions with the lowest participation on Brazil´s GDP) are the macro regions in which the distribution of HEI´s is most uneven. Southeast and South regions demonstrate the most even distribution and the greater number of cities in the groups. São Paulo state has the biggest number of cities on CH+ category– a total of 25 – and is tied with Minas Gerais with 24 cities for the CH-. This displays the influence the São Paulo and Minas Gerais states hold on the development of the country. The best coverage of cities affected by HEI´s (despite the DF that is a State, a city and the nation´s capital) is in the Santa Catarina state with 81,23%.

For the CH+ category the state of Mato Grosso do Sul (MS) in Central West, the states of Rio Grande do Norte (RN), Alagoas (AL) in the Northeast and the states of Roraima (RR), Pará (PA) and Amapá (AP) in the North region will not show any result as, outside of the capital, there is not have a single high-quality HEI in their territory.

When taking into consideration the CH- category Mato Grosso do Sul (MS) in Central West, the states of Maranhão (MA), Piauí (PI), Pernanbuco (PE), Alagoas (AL), Sergipe (SE) in the Northeast and the states of Rondônia (RO), Roraima (RR) and Amapá (AP) in the North region will not show any result as, outside of the capital, there is not have a single HEI in their territory.

Since all states presented a CIH category there is at least one HEI on each state. The state of Mato Grosso do Sul (MS) in Central West, the state of Alagoas (AL) in the Northeast and the states of Roraima (RR) and Amapá (AP) in the

North region displays a situation that only the capital city has an HEI and only the capital´s microregion will benefit from it. The rest of the state´s microregions in all 4 cases have no direct impact as defined by Drucker (2016)

5. Conclusions

Both Tables 2 and 4 displays that the impact follows a similar path in both HDI_I and HDI_E results. On both cases, the highest impact in leveraging the development was the Capital factor as previously discussed. Followed by the capital we can the presence of an HEI will have better results on the city and the findings of Drucker (2016) are supported that the impact and spillover are present locally.

An important information is that the quality of the HEI also has an impact on the HDI indexes. On both comparisons, the cities that were categorized on the CH+ were in average better than the cities categorized on CH-. This points to a conclusion that not only presence, but quality is important. Finally, CIH category has a better result than CNH, showing once again that the impact and spillover effects on microregions is pertinent and the need to consider local impact is necessary to properly develop the country.

When analyzing the possibility to leverage the participation, we can take a closer look at the South macro region of the country, which is the region that can leverage its GDP when compared to the Northeast region. It has half the population - 14,12% against 27,37% (PNUD et al., 2013) - but a better GDP participation - 16,2% against 13,4% (IBGE, 2014) and the coverage of HEI impact can be a determinant factor for it as well as the number of abled engineers (CONFEA, 2016). The 3 states of the macro region have an even distribution (SC = 81,23%, RS = 63,10% and PR = 45,11%).

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