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Essays on the university-industry relation in the periphery in the context of the contemporary capitalism: the Brazilian case

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Policies for science and technology
must always be a mixture of realism and idealism.
Chris Freeman (1921-2010)

INTRODUCTION

The purpose of this essay, which is directly part of my in-progress-Ph.D. work undergone at Campinas State University (UNICAMP), is to discuss with lecturers and other students at the Globelics Academy 2012, some important topics that may enrich my work. One of these topics is how human creativity has been channeled into technical innovation in the periphery and the effective role of research centers and universities. For this reason we should focus on the role of science and universities, especially in the post-1970 and its relations with the productive sector in contemporary capitalism in a peripheral context. The understanding of the true role of universities in the periphery and its role in the productive forces can illuminate proposals for pro-development policies aware of the limitations in the periphery.

The discussion of public policies on science should show the need for certain measures to break the logic of underdevelopment, but what are the political characteristics of the peripheral states? No nation in the world developed without industrialization and urbanization (CANO, 2012). There is no nation that developed without a (national) plan focusing on key actors and institutions.

To disrupt the perverse logic of underdevelopment is necessary, among others, an efficient production system endowed with relative technological autonomy and the ‘visible hand’ of the State guiding an intentionally designed strategy (FURTADO, 1992). Innovation is a fundamental factor for growth and ensure long-term international competitiveness, therefore, should be the top concern of economic development programs.

The development is created by technical progress (as pointed out by Schumpeter), which is the fruit of human creativity, that is, the power of man to innovate (FURTADO, 1981). However, as suggested by Furtado (1981), in the last two centuries human creativity has been channeled towards technical innovation, but innovation does not happen automatically. Therefore, to understand the process of innovation in an economy, it is necessary to insert the 'agents of creativity' in the social practices whose intention is to modify the existing ones. (FURTADO, 1981).

Peripheral technological dependence is a constraint to any attempt for industrial development, especially with regard to the innovation of machinery, industrial equipment and on all machines that produce machines (RAMOS-DELGADO, 2011). That is the reason why peripheral countries should put innovation, technological change and general science and technology to serve their legitimate interests in the contemporary context of science and technology imperialism and strong technological dependence.

As the contribution of scientific knowledge to innovation increases, the role of universities becomes more critical and they remain one important source of knowledge development and diffusion (transfer). Even if the performance of universities within the National Innovation System (NIS) has been checked, several studies have pointed out that they are actually increasing their contribution, particularly through different collaborative mechanisms (GODIN; GINGRAS, 2000; HICKS; KATZ, 1996). Even if the contributions of universities to knowledge diffusion-related activities has been stressed recently, it is possible to find examples of a university's contribution to a firm's innovation process back to the 19^{th} century; what is new nowadays is not the university's capacity of transferring knowledge to the productive sector (which has increased in the past few decades), but the institutionalization of university-industry linkages through the direct involvement of the university (GEUNA; MUSCIO, 2009) and *vice-versa*. This is a new phase of the evolution of universities in mature economies and can be called the 'institutional reconfiguration of the university' (GEUNA, 1999).

Understanding the university-industry relations in the periphery may then shed new light on how to overcome the just mentioned underdevelopment. Thus, one should critically analyze the immature innovation systems and their 'agents of creativity' as many particularities are embedded in the way new relevant knowledge is created and transferred to other agents and how norms and tradition shape the relations among those agents. When talking about the periphery, one must have in mind that the waves of capitalist development change and reshape the challenges and opportunities for these countries 'to catch up' and the universities in those economies have an important role to absorb knowledge from abroad (SUZIGAN *et al.*, 2011).

What regards Brazil, one finds that Brazilian universities are small in scale, concentrated in humanities and applied social science, they have weak links to production activities, and applied research is circumscribed to some fields such as agronomy, mining/metallurgy, and health sciences. Engineering fields germinated very late in Brazil, and graduate courses linking teaching and research activities were ushered in only in the 1960's, nurtured by federal government (SUZIGAN; ALBUQUERQUE, 2009).

Brazilian immature innovation system (ALBUQUERQUE *et al.*, 2005) also faces a lack of synchronization between the incentive regimes of science and technology policies that on the one hand define areas that are important for playing technological and economical catch-up and on the other hand do not have a well-defined policy to allocate human resources to those areas nor does it have an aligned tertiary educational policy. In Brazil, the main locus of knowledge production is the public university which plays an important role in the process of creating and disseminating new scientific knowledge and new technologies through basic research, applied research, development and engineering. They also have the role of supplying skilled labor to meet the demand of the productive sector. Within universities, research staffs are renewed and knowledge is updated.

The university-industry relation in Brazil suffers from structural problems however we cannot say there is no interaction between university and industry in the country. Some studies (FERNANDES *et al.*, 2010; SUZIGAN *et al.*, 2009) show that although these interactions are less complex *vis-à-vis* mature economies and focused on the routine production of the company, such as testing and assistance in quality control, there is also more complex interactions involving bi-directional flows of knowledge, as is the case of cooperative Research and Development (R&D) projects. Contrary to conventional wisdom, we can find examples in history that have demonstrated a close relationship between some Brazilian universities (and research institutes) and industry, however, the maturation of successful cases of university-industry interactions took time and was the result of a process of a long-term institutional building with strong support and intervention of the Brazilian government.

One example of such successful university-industry relation can be the case of the Brazilian Aeronautical Company (*Empresa Brasileira de Aeronáutica* - Embraer) which had benefited from the proximity to the Technological Institute of Aeronautics (*Instituto Tecnológico de Aeronáutica* - ITA) and another one can be the rich interaction between the National Steel Company (*Companhia Siderúrgica Nacional* - CSN), Companhia Vale do Rio Doce and the Department of Metallurgy and Material Engineering of the Federal University of Minas Gerais (UFMG), which resulted in good performance for mining and the Brazilian steel industry (SUZIGAN; ALBUQUERQUE, 2011).

This essay may present the universities' role for economic development taking into account the periphery reality after the 70's. Section 2 provides a characterization of the university system in Brazil.

1 UNIVERSITIES' ROLE FOR ECONOMIC DEVELOPMENT

Countries' innovation efforts are not homogeneous. Some, especially those in the Global North, have shown greater innovation efforts in research and development (R&D) over the past decades when compared to those in the Global South. The importance of R&D lies in the fact that it is a driver for the process of both knowledge and technological accumulation enabling development from what was called 'windows of opportunities' (PEREZ, 2001). Thus, chances for development depend on each of the opportunity achievements made in previous phases, indicating the path dependency of the development process. These achievements should reflect a sound understanding of the technological paradigm, the new knowledge and ability to absorb/produce new technologies, and the existence of available infrastructure. We need to have in mind that knowledge is a type of power

> (...) knowledge is power and whoever is able to develop or acquire and to deny the access of others to a kind of knowledge respected and sought by others; and whoever can control the channels by which it is communicated to those given access to it, will exercise a very special kind of structural power. (…) Today the knowledge most sought after for the acquisition of relational power and to reinforce other kinds of structural power (…) is technology. The advanced technologies of new materials, new products, new systems of changing plants and animals, new system of collecting, storing and retrieving information – all these open doors to both structural power and relational power. (STRANGE, 1994, p.23-24).

The new knowledge and technologies production reflects the importance of investment in R&D, education and training, which are considered essential for capital accumulation, economic growth, technological know-how and socio-economic development. However, investment in human capital is not the single solution for development *per se*. In a knowledge-based economy, not only is the creation of knowledge relevant, but also the creation of relevant knowledge.

In Latin American countries, the main *locus* of knowledge production is the university (AROCENA; SUTZ, 2001). Eight different functions (or outputs) of modern research universities that may lead to economic development impacts can be identified: creation of knowledge, human-capital creation, transfer of existing know-how, technological innovation, capital investment, regional leadership, knowledge infrastructure production and influence on the regional milieu. Each one of the outputs mentioned may cause a different pattern of effects on the economy, ranging from the direct and indirect effects of university spending to productivity gains in private companies, from the creation of spin-off enterprises, and the capacity to sustain long-term development and growth (GOLDSTEIN; DRUCKER, 2007).

In other words, universities play an important role in the process of creating and disseminating new scientific knowledge and new technologies through basic research, applied research, development and engineering. They also have the role of supplying skilled labor to meet the demand of the productive sector. Within universities, research staff are renewed and knowledge is updated (MARCOVITCH, 1999).

Moreover, universities can be seen as strategic agents for 'catching-up' once they contribute to the scientific and technological development of the country. These are the major drivers able to ensure innovation and lead to economic and social changes. Scientific-technological development is a dynamic process and is the result of a collective interaction among different economic agents, especially since the new technological paradigms are permeated by a scientific knowledge which is close to the knowledge frontier; hence it is strategic to promote an active role of the universities and to tighten the university-industry-government network.

The symbiosis between these three agents, was accounted by Sabato and Botana (1968) and gained new prominence with the 'triple helix' approach (LEYDESDORFF; ETZKIWITZ, 1998; LEYDESDORFF, 2000; ETZKOWITZ *et al*., 2000; ETZKOWITZ, 2003; LEYDESDORFF; MEYER, 2006; LEYDESDORFF, 2010) which recognizes that these actors can play the role of each other, so that the innovative system works properly, complementing the framework proposed by the Innovation System (IS).

2 BRAZILIAN UNIVERTY SYSTEM

The Brazilian university system is relatively recent and it has been in existence for less than a century (MELLO *et al*., 2009; MACULAN; MELLO, 2009). Compared to other Latin American countries, Brazil started relatively late on establishing universities (SUZIGAN; ALBUQUERQUE, 2009). While in some Latin American countries the first universities were established in the 16^{th} century (as in Mexico and Peru) or in the 17^{th} century (as in Bolivia), in Brazil colleges of medicine, law or engineering emerged only in the first half of the 19^{th} century (MELLO *et al*., 2009) and the first university was established solely in 1920, in Rio de Janeiro by the Federal Government. It was 1934 before the state of São Paulo created its own university (MACULAN; MELLO, 2009), namely São Paulo University (USP), which was Brazil' first fully-fledged university (SCHWARTZMAN, 1979).

It is clear that the Brazilian university system had a late development and the history of the country's economy and society had a long-lasting influence, which is embedded in Brazilian higher education institutions' (HEIs) features: small in scale, concentration in humanities and applied social science, weak links to production activities, and applied research circumscribed to some fields such as agronomy, mining/metallurgy, and health sciences. Engineering fields germinated even later in Brazil, and graduate courses linking teaching and research activities were ushered in only in the 1960s, nurtured by federal government (SUZIGAN; ALBUQUERQUE, 2009).

Examining the number of scientific and engineering articles published in some particular fields, that is to say, physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences, Brazil is ranked 15th in the world, contributing 1.59% of all those articles issued (Figure 1) which demonstrates the modest performance of the country *vis-à-vis* the research done in more industrialized countries.

Even with this modest performance and considering that Brazil has an immature Innovation System (ALBUQUERQUE *et al.*, 2005; SUZIGAN; ALBUQUERQUE, 2008) once characterized by weak links between scientific infra-structure and technological activities (ALBUQUERQUE, 2004), science activities in the country are striking with investment and scientific productivity outperforming general trends of growth making the country a new emergent scientific nation (RS, 2011). Nonetheless, the question that should be addressed is: what are the main institutions responsible for science activities and knowledge production in Brazil? Private HEIs are specialized in the teaching mission and those that are dedicated to research are rare exceptions in the country, thus the great amount of scientific knowledge production is accredited mostly to public HEIs (CHIARINI; VIEIRA, 2011), more precisely federally funded universities.

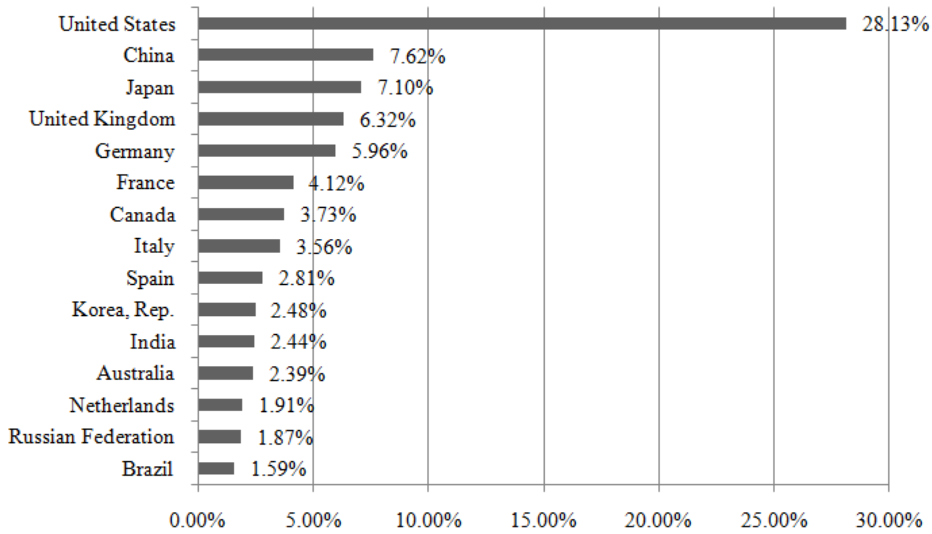

Figure 1 – Scientific and technical journal articles per selected country, %, 2007.
Source: Authors' own. Data sourced from the World Bank Data Catalog. Note: Scientific and technical journal articles refer to the number of scientific and engineering articles published in the following fields: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences.

A particularity of the Brazilian university system is that most private HEIs seem to be specialized in teaching and in some well-defined fields of knowledge (such as management, law, human sciences), with their research activities being almost entirely residual (MACULAN; MELLO, 2009). This is corroborated by taking into account the number of articles[1] published in national and international journal: Brazilian federally funded universities contribute to 45% of total article publications, in 2008, and if we sum up to this percentage the publications of the three São Paulo state funded universities – State University of Campinas (UNICAMP), State University of São Paulo (USP) and Paulista State University (UNESP) – the total percentage reaches nearly 66%.

According to the Brazilian Ministry of Education and Culture (MEC) in 2009 there were 186 Brazilian universities of which approximately 53% were public (federally, state or municipal funded) and about 47% were private. Nevertheless, if all HEIs (universities, university centers and colleges) are considered, there were 2,314 institutions of which only about 10% were public (table 1). In 2010 three more federal universities were legitimized and established, accounting for a total of 58 federally funded universities, which are unequally distributed throughout the Brazilian territory. 33% of those universities are concentrated in the Southeast region while only 9% are in the Central-west region. The former region has 4.75 federally funded universities per state whereas the latter has 1.25.

[1] Here we are considering all fields of knowledge, not only the scientific and engineering articles as the data available by the World Bank.

Table 1 - Total Brazilian HEIs and Universities, 2009.

			HEIs Total	Universities Total	HEIs %	Universities %
Brazil			**2,314**	**186**	**100**	**100**
	Public		245	100	10.59	53.76
		Federal	94	55	4.06	29.57
		State	84	38	3.63	20.43
		Municipal	67	7	2.90	3.76
	Private		2,069	86	89.41	46.24
North			**147**	**14**	**6.35**	**7.53**
Northeast			**448**	**35**	**19.36**	**18.82**
Southeast			**1,090**	**80**	**47.10**	**43.01**
South			**386**	**43**	**16.68**	**23.12**
Center-West			**243**	**14**	**10.50**	**7.53**

Source: Authors' own. Data sourced from Brazilian Ministry of Education.

It is worth mentioning that the title of new emergent scientific nation (RS, 2011) granted to Brazil does not mean it has overcome structural problems associated with Latin American countries, such as illiteracy. One crucial difficulty faced by those countries is to raise the number of undergraduate students, especially in some specific areas as engineering. In 2008, for instance, there were 5,958 millions of enrolments in Brazilian tertiary education compared to the 18,248 million in the USA or 3,939 million and 3,204 million in Japan and Republic of Korea (much smaller than Brazil) respectively[2].

Brazilian domestic expenditure on R&D is increasing along the years but it is still way behind more developed economies. For instance, in 2008, while the Gross Domestic Expenditure on R&D (GERD[3]) expressed as a share of GDP reached 1.13% in Brazil, while in Germany GERD was 2.53[4] and in Japan 3.44[5]. Brazilian performance is better than many Latin American countries like Mexico (0.37[6]) (table 2), but it does not mean we have a mature innovation system. Although, Brazil passed through an inflationary stabilization process, actual macroeconomics policies[7] are not able yet to stimulate long term investments as the ones related to innovation[8].

[2] Global Education Digest 2010, from Unesco.

[3] According to the OECD, GERD is consists of the total expenditure (current and capital) on R&D by all resident companies, research institutes, university and government laboratories, etc. It excludes R&D expenditures financed by domestic firms but performed abroad.

[4] Data available for 2007.

[5] Data available for 2007.

[6] Data available for 2007.

[7]Appreciation of the national currency, Real, and high interest rates increased the external vulnerability of the country and led to inhibition of productive investment and the resumption of economic growth (CANO; SILVA, 2010).

[8] Coutinho (2005) demonstrated that characteristics of macroeconomic systems determine and model the various microeconomic decisions, among them financing pattern and technical changes to be implemented. The interest rate policy is important for determining the cost of capital to private sector and the exchange rate determines decisions on production, investment and debt financing. The combination of interest rates and exchange rates, therefore, will provide the business sector to calculate the risk/return on investment.

Table 2 - GERD as a percentage of GDP, selected countries

	1994	1995	1996	2000	2001	2002	2003	2004	2005	2006	2007	2008
France	2.32	2.29	2.27	2.15	2.2	2.23	2.17	2.15	2.1	2.1	2.04	2.02
Brazil	0.85	0.8	0.72	1.02	1.04	0.98	0.96	0.9	0.97	1	1.1	1.13
China	0.64	0.57	0.57	0.9	0.95	1.07	1.13	1.23	1.34	1.42	1.44	-
Germany	2.18	2.19	2.19	2.45	2.46	2.49	2.52	2.49	2.49	2.53	2.53	-
India	-	-	0.69	0.81	0.84	0.81	0.8	0.79	0.84	0.88	0.87	0.88
Japan	2.79	2.92	2.81	3.04	3.12	3.17	3.2	3.17	3.32	3.4	3.44	-
Korea	2.23	2.27	2.33	2.3	2.47	2.4	2.49	2.68	2.79	3.01	3.21	-
Mexico	0.27	0.28	0.28	0.34	0.36	0.4	0.4	0.4	0.41	0.39	0.37	-
Russian Federation	0.84	0.85	0.97	1.05	1.18	1.25	1.28	1.15	1.07	1.07	1.12	1.03
United Kingdom	1.97	1.91	1.83	1.81	1.79	1.79	1.75	1.69	1.73	1.76	1.82	1.88
United States	2.41	2.5	2.54	2.71	2.72	2.62	2.61	2.54	2.57	2.61	2.66	2.77
OECD total	2.04	2.05	2.08	2.19	2.23	2.2	2.2	2.17	2.21	2.24	2.28	-

Source: Authors' own. Data sourced from OECD Factbook 2010: Economic, Environmental and Social Statistics.

Breaking GERD by source of funds, it is possible to see the contribution of different sectors (financed by industry, by government, by other national sources and by abroad). As it is shown on table 2, GERD financed by industry has an important share in Japan (77.7% of GERD's fund comes from industry), Korea (73.7), Germany (68.1) while in Brazil, GERD financed by industry reached only 0.56%, but it has been growing.

Table 2 - Percentage of GERD by source of funds, by selected countries, 2007.

	Financed by industry	Financed by Government	Financed by other national sources	Financed by abroad
France **	52.4	38.4	2.2	7.0
Brazil	0.56[1]	-	-	-
China	70.4	24.5	-	1.3
Germany **	68.1	27.8	0.4	3.8
Japan	77.7	15.6	6.3	0.3
Korea	73.7	24.8	1.3	0.2
Mexico *	46.5	45.3	-	-
Russia	29.4	62.6	0.7	7.2
United Kingdom	47.2	29.3	5.8	17.7
United States	66.4	27.7	5.8	-

Source: Authors' own. Data sourced from OECD, Main Science and Technology Indicators, Vol. 2010/1. Note: (*)Data available for 2005; (**)Data available for 2006. (1) Data sourced from Brazilian Science and Tecnology Ministry

There is no data available regarding Higher Education Expenditure on R&D (HERD) funded by industry in Brazil; however we could use data from Brazilian Innovation Survey (*Pesquisa de Inovação Tecnológica* - PINTEC) that points industrial spending on innovations activities by type of activities. In 2008, HERD financed by industry in China reached 34.6% and 28.6% in Russia (table 3).

Table 3 - Percentage of higher education expenditure on R&D (HERD) financed by industry, selected countries.

	1995	2003	2004	2005	2006	2007	2008
France	3.3	2.7	1.8	1.6	1.7	1.6	1.6
Germany	8.2	12.6	13.2	14.1	14.2	14.2	-
Korea	22.4	13.6	16.1	15.2	13.7	14.2	12
USA	6.8	5.3	5.1	5.1	5.4	5.6	5.7
China	-	35.9	37.1	36.7	36.6	35.1	34.6
Russia	27.5	27.9	32.6	29.3	29.3	31	28.6

Source: Authors' own. Data sourced from OECD, Main Science and Technology Indicators, Vol. 2010/1.

3 FIELDS OF KNOWLEDGE

By fields of knowledge we refer to the subject areas or disciplines into which knowledge is frequently classified according to the categories proposed by the Coordination of Improvement of Higher Education Personnel (CAPES), which is a Foundation within the Ministry of Education and Culture in Brazil. The following large areas are identified: agricultural science; biological sciences; exact and earth sciences; health sciences; humanities; applied social sciences; engineering; and linguistics, arts and literature.

Analyzing the research groups according to the classification proposed by CAPES, it is possible to note that the highest percentage of research groups registered within the National Council for Scientific and Technological Development (CNPq) is in humanities (almost 19%), followed by exact and earth science (nearly 17 %) and engineering (13%). If we examine the distribution of Brazilian researchers by fields of knowledge, once again the biggest concentration is in humanities (19.56%), followed by health sciences (17.97%). The biggest concentration of article publications taking into account all Brazilian HEIs is in health science (24.69%) and engineering accounts only for almost 9% of total publications in the country (Table 4).

It is worth acknowledging that in Brazil there is a large allocation of human resources to humanities, applied social sciences and linguistics, arts and letters (which together account for almost 37% of researchers) and only 13% of researchers are allocated in engineering. Brazil may not be producing the quantity of relevant human resources required to compete in the world's hi-tech markets. This distortion towards humanities and applied social science in the distribution of researchers by area of knowledge may be directly related to the predominance of HEIs offering a number of course openings that demand little investment in equipment such as management, law and other human sciences (MELLO *et al.*, 2009). The same conclusion can be made if the federally funded universities plus USP, UNESP and UNICAMP are analyzed: the number of researchers allocated in humanities, applied social sciences and linguistics, arts and letters account for almost 35% (Figure 2).

Table 4
Distribution of research groups, researchers, articles, post-graduation Programs, post-graduation student, by fields of knowledge, all Brazilian HEIs, %, 2008.

	Research Groups	Researchers	Publication of research articles	Technical production	Post-graduation programs*	Post-graduation student*
Agricultural Science	9.55	10.37	15.72	4.02	10.98	9.44
Biological Science	11.83	11.33	18.14	21.17	8.10	7.62
Health Science	17.38	17.97	24.69	18.09	16.86	14.43
Exact and Earth Science	11.03	10.03	13.23	18.62	10.09	9.63
Humanities	18.51	19.56	10.05	3.98	14.25	16.99
Applied Social Science	12.08	12.23	6.50	2.54	12.69	12.64
Engineering	13.28	12.88	8.96	30.80	11.02	14.83
Linguistics, Arts and Literature	6.35	5.63	2.70	0.78	5.41	6.45
Multidisciplinary	n/a	n/a	n/a	n/a	10.59	7.98
Total	**100**	**100**	**100**	**100**	**100**	**100**

Source: Authors' own. Data sourced from the Directory of Research Groups of the National Council for Scientific and Technological Development (CNPq). *Data sourced from GeoCapes (Statistical Data from the Coordination of Improvement of Higher Education Personnel - CAPES). Note: Here we considered all public and private HEIs in Brazil. Note: Post-graduation programs refer to the number of master and doctoral programs. Bibliographic production refers to articles published in nationally and internationally indexed journals; technical production here refers to the sum of the production of software and technology products which had patent registration.

A peculiarity of the Brazilian tertiary education is that the public HEIs are the main supporter of the public system of research, especially thanks to the post-graduate programs sustained by those institutions. In 2008, the Coordination of Improvement of Higher Education Personnel (CAPES) had 2,718 registered programs that were offered in the country; humanities, applied social sciences and linguistics, arts and letters corresponded to nearly 32% of all programs. About 46 000 students were enrolled in post-graduate programs in the Brazilian HEIs in the same period: 36% of whom matriculated in humanities, applied social sciences and linguistics, arts and letters. Over the next few years the country will put in the market work force about 54 thousand Masters/Doctors from the aforementioned areas while only less than half of it will be made of engineers.

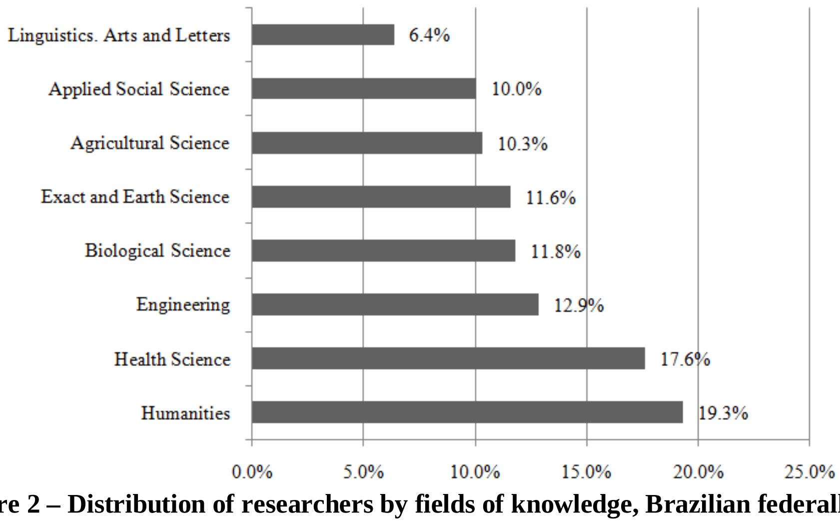

Figure 2 – Distribution of researchers by fields of knowledge, Brazilian federally funded universities and USP, UNESP and UNICAMP, 2008.
Source: Authors' own. Data sourced from the Directory of Research Groups of the National Council for Scientific and Technological Development (CNPq).

It has been ascertained that not every type of research conducted by Brazilian HEIs is destined for strategic sectors defined by the industry and the country's development. We identify strategic sectors that can help the country's development taking the sectors defined by the Brazilian Industrial, Technological and Foreign Trade Policy (PITCE) as software, biotechnology, nanotechnology, biomass, capital goods, semiconductors and pharmaceuticals[9]. Accepting the aforementioned areas as strategic and 'leading to the future,' we propose that they have the potential radically to change processes/products, which is why there should be a better allocation of resources to these sectors. It is possible to cur across these sectors with the fields of knowledge proposed by CAPES referred before (table 5). Although a direct correlation between fields of knowledge (CAPES) and strategic areas (PITCE) may be identified, nothing prevents research on a specific strategic area being conducted by researchers from other fields of knowledge. Chiarini and Vieira (2011) show that although 'software' belongs to Physical and Earth Sciences, there are researches related to software performed in other fields such as Agricultural, Engineering, Health Sciences, Social Sciences, Humanities, and even linguistics, Arts and Letters; the same may happen to other strategic sectors.

Table 5 - Fields of knowledge *versus* strategic sectors of PITCE

Fields of knowledge - CAPES	Strategic sectors - PITCE
Exact and Earth Sciences	*Software*
Engineering	Semiconductors Capital goods
Health Sciences	Pharmaceuticals
Agricutural Sciences	Biomass
Life Sciences	-
Applied Social Sciences	-
Humanities	-
Linguistic, Arts and Letters	-
Multidisciplinary	Biotechnology Nanotechnology

Source: Chiarini; Vieira (2011).

It is not the intention of this paper to suggest or to advocate the exclusion of research lines that do not fit the priority sectors of industrial and scientific and technological policies of the country. It is understood that they are important tools for understanding the regional, historical, cultural, economic and social dynamics (CHIARINI; VIEIRA, 2011). Nevertheless, we want to emphasize the importance that needs to be given to studies focused on the HEI priority areas for scientific development and technology as these are in line with the themes of

[9] The Industrial, Technological and Trade Policy (PITCE) was launched in 2004, under President Lula da Silva as a way of valuing innovation as a means of development, influenced by the evolutionary school. The PITCE recognizes that certain knowledge-intensive areas are 'future carrier' and strategic and therefore they should be encouraged, as a result of joint efforts. Thus, this policy aims to guide public action in pursuit of dynamic comparative advantages and productivity increase. (CAMPANARIO, *et al*., 2005).

Innovation Systems and is supported by the experience of countries that encouraged academic background in science and technology. This is the case in India which has stimulated the formation of qualified personnel in science and technology with emphasis on areas such as exact sciences and engineering.

4 PUBLIC INVESTIMENT IN BRAZILIAN UNIVERSITIES

Federal agencies like the Coordination of Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq) in Brazil foster research through non-recoverable funds. State agencies have the same objective and the Research Support Foundation of São Paulo State (FAPESP) is by far the most important of them.

When we look at the non-recoverable funds granted by FAPESP, there was a real growth of 22.32%, between 2006 and 2010. In 2010, FAPESP investments that supported researches in Brazilians HEIs located in São Paulo State amounted to US$ 443.1 million and 11.06% of FAPESP resources to support research were directed to research in technological innovation. Considering CAPES investments, there was a real growth of 30.9%, between 2006 and 2008. In 2008, this investment was US$ 447.2 (table 6)

Table 6
Financial resources to research, CNPq, CAPES and FAPESP, 2006-2010, U$ million

	CNPq	CAPES	FAPESP
2006	408.6	260.3	239.8
2007	617.5	308.7	282.1
2008	635.7	447.2	347.7
2009	665.2	n/a	340.2
2010	900.0	n/a	443.2
2006-2008 Real growth	20.60%	30.90%	10.50%
2006-2010 Real growth	46.02%	n/a	22.32%

Source: Authors' own. Data sourced from CNPq, CAPES and FAPESP. Note: To calculate the real growth we used the IPCA inflation series from IPEAdata to deflate the R$ values.

Between 2006 and 2010, there was a real growth of 46.02% of investments in research of CNPq in Brazilian HEIs. The distribution of resources for research in Brazilian HEIs shows that about only10% of financing goes to areas of knowledge that have no relation to the strategic technological sectors of PITCE presented previously, as Humanities, Applied Social Sciences and Linguistics, Art and Letters.

In 2008, Agronomy, Medicine, Engineering; Physics; Chemistry and Pharmaceuticals; and Computer Science received together 43.3% of US$ 635.7 million that CNPq invested in research projects, events and post graduate scholarships (in Brazil and abroad) (Figure 3).

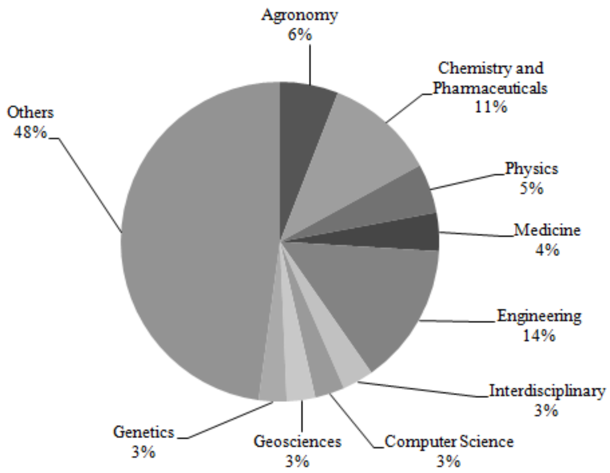

Figure 3 – Distribution of investments in research per specific fields of knowledge, Brazilian HEIs, 2008.
Source: Authors' own. Data sourced from the National Council for Scientific and Technological Development (CNPq).

These three agencies (Capes, FAPESP and CNPq) are very important in supporting Brazilian HEIs research and knowledge production. However, here we take into account only the investment of CNPq to support research projects. There are two reasons that justified this choice. The first is institutional: the choice of analyzing only this research supporter agency is because of its aim to promote and stimulate the scientific and technological development of the country and to contribute to the formulation of national science and technology policy and it is linked to the Ministry of Science and Technology. It is also recognized as the main source of non-recoverable fund for research as was identified in Table 6. The second reason is determined by our research in this paper: it is very difficult to find investment data on other institutions in research by HEIs, and this is true for all the other data investigated in this paper. Therefore we based our research on data sourced from CNPq.

In 2008, of the US$ 635.7 million, CNPq invested US$ 195 million only in research projects (of which 64% were placed in the federally funded universities plus USP, UNESP and UNICAMP.) Of this 64%, 14.09% was allocated to USP (figure 4).

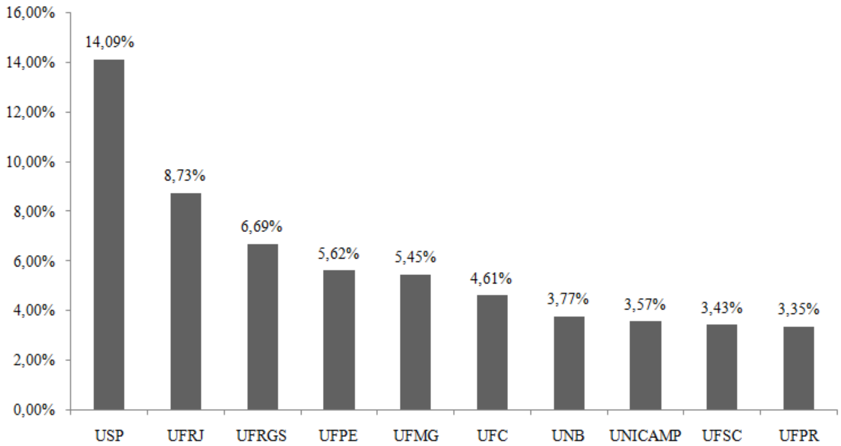

Figure 4 – Percentage of CNPq investment in research project, selected federally funded university plus USP, UNESP and UNICAMP, 2008.
Source: Authors' own. Data sourced from the the National Council for Scientific and Technological Development (CNPq) Statistics on Science and Technology.

As opposed to what happens to the large amount of human resources allocated within humanities, applied social sciences and linguistics, arts and letters (together accounting for almost 37% of researchers, as was shown previously in section 3.2), Brazil seems to allocate financial resources more in Biological Science (21.7%) and Engineering (15.2%) which seems to align with the country's Industrial and Technological Policy (Table 7). Thus, if Brazil has a lag in innovation it may well cbe aused due to the lack of human resources in areas like engineering rather than from financing of research.

Table 7
Distribution of Financing to Research per field of knowledge, 2008.

	US$	%
Biological Science	42,428,019.00	21.7
Engineering	29,775,138.00	15.2
Exact and Earth Science	29,284,522.00	15.0
Agricultural Science	29,261,384.00	15.0
Health Science	28,622,003.00	14.7
Humanities	9,682,300.00	5.0
Applied Social Science	6,594,161.00	3.4
Linguistics. Arts and Literature	1,382,026.00	0.7
Not available/not applicable/others	18,262,863.00	9.4
Total	**195.292.416,00**	100

Source: Authors' own. Data sourced from the National Council for Scientific and Technological Development (CNPq) Statistics on Science and Technology.

FINAL CONSIDERATION

Brazil is not appropriately allocating resources to produce new techno-scientific knowledge to compete in the world's technologically advanced markets in order to act on 'windows of opportunities' and that the country is not ready to act in an internationally competitive environment. Brazil seems to allocate financial resources more to biological sciences and engineering research which aligns with the country's Industrial and

Technological Policy, however, it was demonstrated that not every type of research conducted by Brazilian HEIs was destined for strategic sectors. This was also true for the allocation of human resources in research.

In Brazil there is a large allocation of human resources within humanities, applied social sciences and linguistics, arts and letters (together accounting for almost 37% of researchers) whereas only 13% of researchers are allocated to engineering. Brazil may not be producing the quantity of relevant human resources required to compete in the world’s hi-tech markets. This is very worrisome since the country needs qualified human capital in technological areas if it is to realize its goal of playing ‘catch-up’ with developed economies. Furthermore, training people in areas like health and education is also crucial in the Brazilian context, in order to meet needs that are both social and economical bottlenecks in the country.

The empirical findings presented suggest some normative actions: science and technology policies should make it possible for the country to enter a new pattern of industrial growth relying heavily on basic and applied research in the Brazilian universities. Thus, there should be a better coordination inducing scientific research to sectoral areas such as software, biotechnology, nanotechnology, biomass, capital goods, semiconductors and pharmaceuticals. This means that “research and development activities should be selective and clearly associated with broader processes of innovation based on the transfer, diffusion and absorption of technological competence” (SCHWARTZMAN, S., *et al*., 1995, p. 33). The state's role in providing highly qualified human capital is crucial in Brazil. The public HEIs are the main supporter of the public system of research, especially thanks to the pos-graduation programs sustained by those institutions.

Other important questions should be taken into account to conclude the PhD. work:

- Economic and political elements of the contemporary international order which outline the main features of technological imperialism imposed on the periphery;
- The effective role of science and technology in the periphery;
- The possibility of placing innovation, technological change and general science and technology to serve the legitimate interests in a context of peripheral imperialism of science and technology and strong technological dependence;
- How science and technology can be seen as 'productive force' in peripheral economies;
- Study of university-business relations in the periphery in the post-1970, in Brazil;
- Suggestions for Public Policies (ST&I and higher education) in Brazil;
- Prospects for overcoming underdevelopment in Brazil.

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