Technological gap, social gap:

an investigation on the relationship between scientific and technological production and human development in Brazil (preliminary version)

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Introduction

This article evaluates the relationship between scientific and technological production and welfare conditions in Brazil. The starting point is the 2001 Human Development Report. This report suggests the existence of mutual causal links between technological innovation and human development, generating a virtuous cycle of economic and human development.

This article investigates the relationship between technological dimension and human development dimension within Brazil. In this paper we use different data sets, scientific technological production statistics, human development statistics and welfare statistics, which can contribute to a better understanding of the Brazilian case and its position in the international scenario.

This article is organized as follows. The first section sums up the most important results of the 2001 Human Development Report, systematizing the multiple connections between technology and welfare and identifying Brazil's position in the international ranking. The second section presents Brazil's international position in technological and social development. The third describes our data set pointing out their problems and limitations. The fourth and fifth introduce the methodology used in this study and the main findings of statistical analysis. Finally, the sixth section concludes the paper.

1 Technology, human development and economic growth

Abramovitz (1986) emphasizes the importance of the "social capability" concept to the understanding of catching up process. The concept of social capability points out that "tenacious society characteristics normally account for a portion, perhaps a substantial portion, of a country's past failure to achieve as high a level of productivity as economically more advanced countries" (p. 387). Such a concept allows the identification that "a country's potential for rapid growth is strong not when it is backward without qualification, but rather when it is technologically backward but socially advanced" (p. 388). Social capability involves, therefore, such issues as education, financial institutions and political institutions. “The state of education embodied in a nation’s population and its existing institutional arrangements constrains it in its choice of technology” (p. 388). The relationship between science-industry-technology as well as general and technical education will make up the remaining elements of social capability.

The 2001 Report (UNDP, 2001) synthesizes several studies, pointing out the multiplicities of channels determining the interactions between technology and human development. This scheme suggests a set of interactions among the several components involved in pointing out the existence of causality relationship in several directions. The scheme shows a two-way causality between human development and technological development. This points to the presence of a “virtuous circuit” through an intermediary link, which is economic growth.

How are these multiple influences processed?

Technological innovations affect human development in two ways. Directly, by making available goods which directly affect health, nutrition, and population living conditions. Examples of these goods are drought-resistant plant species, inoculations, clean energy, Internet, etc (UNDP, 2001, p. 28). And indirectly, through technological innovations, which affects human development as a result of its impact on economic growth by means of productivity gains.

One important outlet for the direct influence of technological breakthroughs in human development occurs through the impacts of scientific technological development on health. For instance, UNDP affirms that “ medical breakthroughs such as immunizations and antibiotics resulted in faster gains in Latin America and East Asia in the 20th century than Europe achieved through better nutrition and sanitation en the 19th century. Human health and survival began to improve dramatically in both regions in the 1930’s. By the 1970s life expectancy at birth had climbed to more than 60 years, achieving in four decades an increase that took Europe a century and a half starting in the early 1800s” (UNDP 2001, pp. 28-29).

The relationship between technological process and health is well analyzed by Wang et al (1999) in a study also discussed in the 2001 Human Development Report. This study evaluates the relative conditions of income, education and technical progress for the advances in health status. Wang et al (1999, pp 18-19) found that technical progress is responsible for 45% of the reduction in the mortality rate of infants below five years and for 45% of the increase in women’s life expectancy.

On the other hand, human development affects technological development by extending the reach of higher educational levels, which make up important factors in the creation and diffusion of innovations. The report points out that, along with human development, there is a greater availability of both scientists undertaking research activities and workers able to learn and dominate new technologies.

Connecting these causal senses, the report suggests that "human development and technological advance can be mutually reinforcing, creating a virtuous circle" (UNDP p. 28). Regarding technological progress, the Report suggests that economic growth has a causal relationship in both directions. On the one hand, economic growth contributes to technological progress, making available resources for research activities and for the constitution of scientific technological infrastructure. On the other hand, technological innovation contributes to expanding economic productivity.

As far as human development is concerned, the Report suggests only one-way causality: the effect of economic growth on human development. However, other studies can be used to suggest that there is also an arrow linking human development and economic growth.

Fogel (1994), for example, demonstrates the influence of nutrition gains on per capita income growth. The 1993's World Bank Report systematizes some aspects in which advances in health directly influence economic growth. The following points are highlighted: labour productivity gains; better use of natural resources; benefits that education can bring in to the future generations; cost-cutting in medical assistance; health investments effects on poverty reduction. In adding up the effects, we reach the conclusion that "improvement in health conditions should lead to an improvement in nationwide economic performance" (p. 23) and that " the data point out that better health conditions mean faster growth" (p.25).

To the WHO (1999), advances in health influence economic growth directly by determining productivity gains and, indirectly, through the improvement of learning conditions and all of the effects arising from a better educational performance.

It's important to consider, however, that the international setting is marked by great inequalities in terms of income (UNDP 2001, pp. 16-20) living conditions and human development (UNDP, 2001, pp. 141-144), scientific and technology resources. As far as health is concerned, the world setting described by WHO can be summed up as a dual challenge: "emerging epidemics and persisting problems" (WHO, 1999, p. 13-27). This information is important in order to discuss the reasons for the lack of a virtuous circuit between technological progress and human development in several regions of the planet.

2 Locating Brazil’s international position

In light of these discussions, we seek to identify the Brazilian position in the world scenario. This section is dedicated to this task, i.e., to describe briefly the welfare and innovation systems of Brazil. The country is presented as an “immature” one, marked by a relative delay in social and economic terms (ALBUQUERQUE, 2003). We also organise data on scientific and technology production, along with human development indicators for Brazilian cities in the year 2000.

As the statistics presented in table 1 reveal, Brazil holds an intermediary position in comparison to the other economies of the sample, being classified as a country of ‘medium human development’ (HDI<0,8) and as a ‘dynamic follower’ in terms of technology capabilities (TAI<0,35)[1]. Along with Brazil, other countries hold a similar position, sharing close characteristics, such as India, Mexico and South Africa. As suggested by Albuquerque (2003), they are considered economies with “immature systems of innovation”, meaning that they possess an incipient but somewhat organized scientific and technological infrastructure, characterized by weak interactions among science, technology and economic growth. They persist to stand behind the more advanced nations, once they have not overcome a scientific threshold that instigates a virtuous cycle of interactions (BERNARDES; ALBUQUERQUE, 2003). Expenditures on R&D confirm this point, as the immature NSIs show values much lower than those of the leading countries (bellow 1%GDP).

These countries are also distinguished by a high degree of inequality, in terms of both income and spatial localization. Evaluating data regarding income concentration, we can conclude that South Africa, Brazil and Mexico have Gini Indices above 50[2]. India appears to have a more homogenous poverty distribution: it combines the lowest Gini Index with the lowest per capita GDP among the four countries. From the technological viewpoint, there are indications of geographical concentration of the innovative activities: in all four countries, the leading state or province holds over 40% of the number of patents in the country (USPTO, 2002). This pattern of geographical concentration is repeated in scientific activities, except for India (ISI, 2002).

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[1] The Indicator of Technology Achievement (ITA) created by UNDP is based on four elements – creation of new technologies, diffusion of old technologies, diffusion of recent technologies and human qualification. The Human Development Indicator is formed by life expectancy, income and education.

[2] In the 20001 Human Development Report (UNDP, 2002, p. 188), the Gini Index ranges from 0 (perfect equality) to 100 (perfect inequality).

The evidence of inequality both in income distribution (an indicator associated with welfare) and in distribution of scientific and technological activities foster an in-depth investigation into the Brazilian case. This investigation is important because inner inequality, both in scientific technological activities and in welfare indicators can be a determining factor of Brazil's international position, according to TABLE 1.

TABLE 1

Comparison between indicators of Human Development and Technical Progress: selected countries

Country	HDI Position	HDI	TAI Position	TAI	Expenditures R&D (%GDP)	Illiteracy rate (% > 15 years)	Gini Index	Life expectancy at birth (years) (1999)
Finland	6	0.934	1	0,744	2,8	99,0[1]	25.6	76.8
Japan	9	0.928	4	0,698	2,8	99,0[1]	24.9	80,8
USA	10	0.925	2	0,733	2,6	99,0[1]	40.8	77,4
South Korea	27	0,875	5	0,666	2,8	97,6	31.6	74,7
Mexico	51	0,790	32	0,389	0,3	91,1	51.9	72.4
Brazil	69	0,750	43	0,311	0,8	84,9	59.1	67.5
South Africa	94	0,702	39	0,340	0,7	84,9	59.3	53.9
Nicaragua	106	0,635	64	0,185	na	68,2	60.3	68.1
India	115	0,571	63	0,201	0,7	56,5	37.8	62.9
Mozambique	157	0,323	72	0,066	na	43,2	39.6	39.8

Source: Authors elaboration from Albuquerque (2003) and UNDP (2001).

Note: ([1]) This number was used for the calculation of HDI

(na) Not available

In terms of technological production, Brazil, along with other immature countries displays the following features, in accordance with Albuquerque (2003):

a) a great magnitude of foreigners assignees whose first inventor is resident – 26% in Brazil for patents registered in USPTO (1981-2001);
b) a significant portion of patent assignees are individuals (Brazil 26%);
c) public and foreign companies are the largest patenting firms in the American Office, i.e. Petrobras and Companhia Vale do Rio Doce;
d) in the national Office (PTO), universities and research institutes play a major role in patenting activities, along with public enterprises – for instance Unicamp, Embrapa and Fiocruz;
e) there exists a technological specialisation in patent classes related to health – Brazil: leading class (Wipo) A61, Medical and Veterinary Sciences;
f) distinguished pattern of regional concentration ("oligocentric")

TABLE 2 illustrates the high spatial concentration of the Brazilian technological production, using data from cities in the year 2000. It should be noted that all cities presented belong either to the southern or to the southeastern region, what elucidates the type of distribution of our technological activities, characterized by the regime North-South polarization (ALBUQUERQUE *et al.*, 2001).

TABLE 2

Leading patenting cities and their Human Development Indicators- Brazil, 2000

Cities	State	Patents		Human Develop.		
		Total	%	EL[i]	R[ii]	HDI
São Paulo	SP	1499	26,5	0,840	0,843	0,841
Rio de Janeiro	RJ	402	7,1	0,843	0,84	0,842
Belo Horizonte	MG	241	4,3	0,844	0,828	0,839
Curitiba	PR	222	3,9	0,861	0,846	0,856
Porto Alegre	RS	170	3,0	0,863	0,869	0,865
Campinas	SP	144	2,5	0,856	0,845	0,852
Brasília	DF	106	1,9	0,845	0,842	0,844
Caxias do Sul	RS	79	1,4	0,881	0,807	0,857
São Bernardo do Campo	SP	75	1,3	0,845	0,812	0,834
Joinville	SC	71	1,2	0,897	0,776	0,857

Source: Author's elaboration from INPI and Atlas de Desenvolvimento Humano do Brasil

Note: ([i]) Combination of the sub indices of Education and Longevity of M-HDI

([ii]) Sub indice of Income from M-HDI

Considering the spatial localization of the scientific production, clearly it is also very concentrated. The city of Sao Paulo is the leading one, encompassing separately 14, 3% of the country's scientific activity and 26, 5% of the technological one. Rio de Janeiro stands in the second position, being responsible for 11, 4% of the papers published and for 7, 1% of the patents registered.

Table 3 displays the top ten cities in terms of science production, both in total and in per capita values. The rankings differ substantially, it should be observed. But the M-HDI for both groups is higher than the national average.

TABLE 3

Top 10 Cities in Science Production (total and per capita) and related Human Development Indicators - Brazil, 2000

City	State	Papers		Human Develop.			City	State	A*[iii]	Human Develop.		
		Total	%	EL[i]	R[ii]	HDI				EL[i]	R[ii]	HDI
Sao Paulo	SP	2022	14,3	0,840	0,843	0,841	São Carlos	SP	2865,3	0,864	0,795	0,841
Rio de Janeiro	RJ	1606	11,4	0,844	0,840	0,842	Viçosa	MG	1711,5	0,842	0,741	0,809
Campinas	SP	967	6,8	0,856	0,845	0,852	Santo Antônio de Goiás	GO	1609,8	0,788	0,67	0,749
Sao Carlos	SP	553	3,9	0,865	0,795	0,841	Botucatu	SP	1043,3	0,841	0,783	0,822
Belo Horizonte	MG	541	3,8	0,844	0,828	0,839	Campinas	SP	997,5	0,856	0,845	0,852
Porto Alegre	RS	511	3,6	0,863	0,869	0,865	Seropédica	RJ	812,1	0,797	0,684	0,759
Ribeirao Preto	SP	331	2,3	0,871	0,823	0,855	Cachoeira Paulista	SP	698,4	0,835	0,711	0,794
Brasília	DF	264	1,9	0,846	0,842	0,844	Coronel Pacheco	MG	689,7	0,782	0,643	0,736
Curitiba	PR	241	1,7	0,861	0,846	0,856	Florianópolis	SC	686,5	0,878	0,867	0,875
Florianopolis	SC	235	1,7	0,879	0,867	0,875	Ribeirão Preto	SP	655,5	0,870	0,823	0,855

Source: Author's elaboration from INPI and Atlas de Desenvolvimento Humano do Brasil
Note: (i) Combination of the sub indices of Education and Longevity of M-HDI
(ii) Sub indice of Income from M-HDI
(iii) Papers per capita

As previously mentioned, Brazil is considered a country of 'medium human development' (HDI = 0,750 in 1999). Our poverty indicators are very disturbing – HPI-1 equals 12,9%, indicating that this portion of the population lives behind the international poverty line (18th position in the ranking) [3] (UNDP, 2001). Furthermore, inequality also permeates the welfare system, as it seems to follow the localization of the scientific-technology activity, which is concentrated in the southern and southeastern regions, as 1 shows. The average of M-HDI for the South and Southeast has been estimated in 0,808 and 0,791, whereas for the North, Northeast and Center-west in 0,725, 0,676 e 0,793 respectively. It is worth emphasizing here the position of the Center-west region, whose human development indicator is comparable in average to that of the Southeast, although its figures in terms of science and technology do not have a similar representation. This fact is due, partially, to the presence of Distrito Federal (the capital of Brazil), which raises the regional average (M-HDI of 0,844) and to the good levels of education in the region – 0,881 in average, a high value for Brazilian standards.

[3] The Human Poverty Indicator measures human privation in three dimensions: i) a long and healthy life; ii) access to knowledge and iii) descent life standards. For more details, see UNDP, 2001, p. 241.

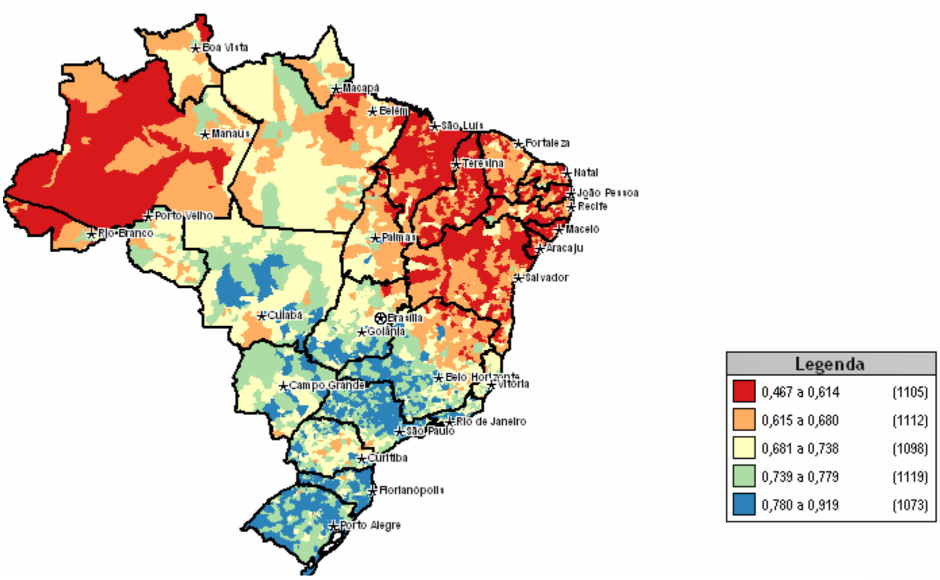


FIGURE 1
Human Development Indicators of Brazilian Cities (2000)
Source: Fundação João Pinheiro, 2001

3 - Descriptions of the variables

Seeking to estimate the relationship between science and technology and the level of human development, we carried out a controlled analysis on a municipal level. Although such a geographical unit takes on a small-scale productivity structure in most cases in Brazil, resorting to information in a broader range, i.e. on a state level would reduce dramatically the number of observations. Two estimation procedures were performed – one using the Negative Binomial Hurdle Model and another using a Simultaneous Equation Model.

We use in our estimation of the Negative Binomial Hurdle Model seven groups of information data: the human development index, urbanization indicators, cultural infrastructure indicators, presence of incentive policies, level of schooling, health status indicators, and scientific technological production.

The Municipal Human Development Index (M-HDI) is set up by means of three dimensions – education, income and longevity[4]. The M-HDI variables are transformed into indices ranking from 0 (worst) to 1 (best) and the combination of these indices into a

[4] This methodology was created by a group of researchers from João Pinheiro Foundation and from the Applied Economics Research Institute (IPEA) and differs somewhat from the HDI of UNDP regarding the definition of income and education variables. Education is measured by two indexes with distinct weights: the rate of literate adults (those older than fifteen able to read and write) (weight 2) and the gross rate of school attendance (weight 1). The income dimension is accounted by means of the city resident average income or by per capita municipal income.

synthesis indicator. Thus, the closer to 1 the indicator is, the higher the level of human development of the city.

The urban infrastructure set takes into account the following variables: the existence of *favelas* or slums, rate of households in urban areas, rate of households with garbage collection services, rate of households with water supply and rate of households with a bathroom. These rates represent the relationship between the households that present such conditions and the total of households in the city. The existence of *favelas* or slums is a dummy variable: 1 if the city has any *favela* and 0 otherwise.

The inclusion of this group of variables enables us to measure the role of urban development[5] in the production of technology, with a direct causal relationship between such variables. In addition, as we are carrying out the analysis on a municipal level, this type of control is still very important in Brazil due to heterogeneity in the economic development. In observing the average of these variables, we realize that 71% of the cities have *favelas* or slums, only 59% of the households are located in urban areas, 59% of the households have water supply and 55% have garbage collection services

The cultural infrastructure variables are: existence of Internet Service Providers (ISPs), bookstores (dummy variable), number of public libraries[6] and number of daily newspapers. These four variables enable us to measure the level access to the information within the cities. The higher the number of ISP's, bookstores, daily newspapers and libraries, the greater the production of patents and papers.

The group of variables related to incentives policies tries to capture the productive capacity of the city. All indicators are binary variables: presence of employment and income generation programs, presence of professional capability program and presence of other type of incentives to economic activities.

The health variables are the rate of child mortality and the number of hospitals beds per capita. The rate of child mortality is calculated by means of the relationship 0 to 1 year of age, and the total number of children born alive. This variable is an indicator of well-being which complements that of access to education.

Statistics for patents and scientific articles contribute towards understanding and mapping the country's scientific technological production. The IBGE's newly published

[5] This group of variables is associated with municipal GDP and, since there is no register of this indicator for all Brazilian cities, we have opted for this group of variables.

[6] For the city of Porto Alegre, the original research data are not available Therefore, we have researched the Bibliotecas de Porto Alegre website which indicate the existence of 18 libraries. In the case of the other cities, without such information, it is impossible to estimate any number, due to the lack of data available.

Research On Technological Innovation (PINTEC) for example, still does not have disaggregated data on the municipal level, which justifies the use of patent data in an effort to draw up this map.

The variables to measure technology generation capacity refer to the number of patents filed with the PTO between 1989 and 1999 and the number of articles indexed with the ISI in 1999. Although the patent register bears the patent-holder’s address, the PTO has not transferred these data to its magnetic register. The only information presented is the patent holder’s state. Such information is important to this work, for it implies the exclusion in the current analysis of the patents whose patent-holders are individuals. Individuals play a major role in the country’s total number of patents (67% in the period 1988-1996).

The data presented in this section, therefore, are restricted to corporation-filed patents. The city is identified by matching the data supplied by the PTO (with the patent- holder identification) with that of RAIS (Social Information Annual Report) which associates the patent holder’s with a city. By crossing both PTO’s and RAIS’s information, we set up the database described in this section.

The PTO data present information on 7.040 different companies, 23.919 patent-holders and/or technological transfer contracts that, between 1999 and 2000, filed patents and or executed technological transfer contracts. Matching such information with that in RAIS allows the identification of the municipal location of 4.201 companies, representing 17.587 patents.

As the patents’ database refers to a longer period (1988 to 1999) and RAIS’s to one year only (1997), some firms that filed patents at the end of the 80’s and beginning of the 90’s may have disappeared (through either bankruptcy or mergers and acquisitions). The small companies play a major role in the total of patents. Out of all participating firms present in the PTO data, 4,001 (56.83% of the total) filed only one patent. The number of cities with at least one participating author from one local institution is 226. The ten cities with greater scientific production account for 69% of the domestic scientific program.

For the estimation of the Simultaneous Equation Model, we have used a slightly different database of science and technology indicators. For the year 2000, there were 8.5560 papers published by ISI, localized in 225 cities, whereas for the year 1999, 9.493 papers were identified in 259 cities. It was used the same methodology to collect data as earlier described. The statistics of patents were collected directly from the website of the PTO for the years

1999 and 2000. It was not necessary to match them with information gathered at RAIS. Patents from both individuals and companies were used not to reduce the sample dramatically (individual's patents account for more than 75% of the total). It contains a total of 5.660 patents localized in 560 cities for the year 2000 and 5.724 patents in 534 cities for 1999. However, taking into consideration only the cities with some scientific and technology production in both years (1999 and 2000), the sample is reduced to 113 observations (out of 5.507 Brazilian cities).

4 Estimating science and technology determination according to human development and municipal infrastructure indicators

As stated above, this paper aims to evaluate the relationship between scientific technological production and welfare in Brazil. Although the relationship between these two variables is a two-way channel, we are initially looking into one way only, i.e., how social well-being is capable of accounting for scientific technological production in Brazil.

Therefore, we have decided to use the Negative Binomial Hurdle Model in order to estimate the relationship between scientific technological production and the degree of human development. This model enables us to estimate the process of decision of patent registration and paper publication as two distinct stochastic processes[7]. This implies a prior consideration of this of data – the number of patent registrations and paper publications make up events which may be considered counting data that take on only nonnegative value and they do not have an upper limit amount. The value associated with those variables stands for the number of times the events occurred.

The first process refers to the decision to produce knowledge and innovation and the second concerns the decision of the number of the patents to be registered and articles to be published. In this case, we can reasonably assume that the agents determining each of these processes are distinct. The first process deals with various decisions – first, to set up a research facility in the city; second, form the viewpoint of the firm, to set up an R&D activity and third, from the viewpoint of the entrepreneurs, to invest either in the development of a new product or in the improvement of an existing one. In the second process, the number of

[7] As the data are censored, some authors suggest estimating the model through the Heckit estimator, arguing that information may be missing due to sample selection problem. Estimating models through to the Heckit procedure however, does not regard these data as count data. In addition, in the case of patents and published papers we do not believe that "zero" arises from sample selection. Rather, it should represent a genuine choice. Thus, the Hurdle model is the most suitable for estimating purposes.

patents registered or papers published depends on the decision related to the volume of investments and/or the number of professionals allocated to innovative activities.

In the first step, we used a logit model to determine if the city has produced scientific technological knowledge and in the second step, we applied the Negative Binomial Model truncated to zero expected number of both patents and articles with positive generation[8] (Cameron and Trivedi, 1988).

Out of a range of 5,507, some cities do not possess any information as to the registers of some of the variables used. We have therefore disregarded such cities, thus reducing the database to 4,969 observations[9]

In the econometric model estimated, we have used the M-HDI index itself as a proxy variable for human development and we have included the remaining independent variables that aim to describe culture infrastructure, degree of access to information and existence of programs of economic incentives in the city.

In M-HDI, health is portrayed by life expectancy on birth which presents an element of inertia and is subject to a lower time variance as it is an indicator describing health conditions across all age groups. Thus, as life expectancy on birth is an average for the whole population's health, there may be changes averaging each other out and we end up with cities a similar value for this indicator under very different health conditions among the age groups. As such the M-HDI do not accurately reflect reality and, therefore, the second specification allows us to infer the level of robustness of the estimated relationships, as we alter the indicators used as proxies for human development.

As mentioned before, M-HDI ranges from zero to one. In the case of Brazilian cities, this index takes on values between 0.4668 and 0.919 and the distribution among the cities is asymmetrical to the right (see figure 2). Because of these characteristics and in order to estimate the logistical model and interpret the coefficients[10], we have set up dummy variables that reflect different degrees of human development among the cities. Eight dummy variables have been defined in such a way as to obtain a number of relatively homogenous

[8] The Hurdle Model is estimated by means of the maximum likelihood method, built with two parametrically independent functions. One function for the traditional logit model and another for Negative Binomial truncated to zero model.

[9] Out of 538 observations excluded, none presents scientific technological production. Observing the distribution of the control variables in this sub-sample, we have found them to be related to cities with a lower level of development. As such, the lack of register seems to he correlated with the degree of development, showing bias in the missing observations.

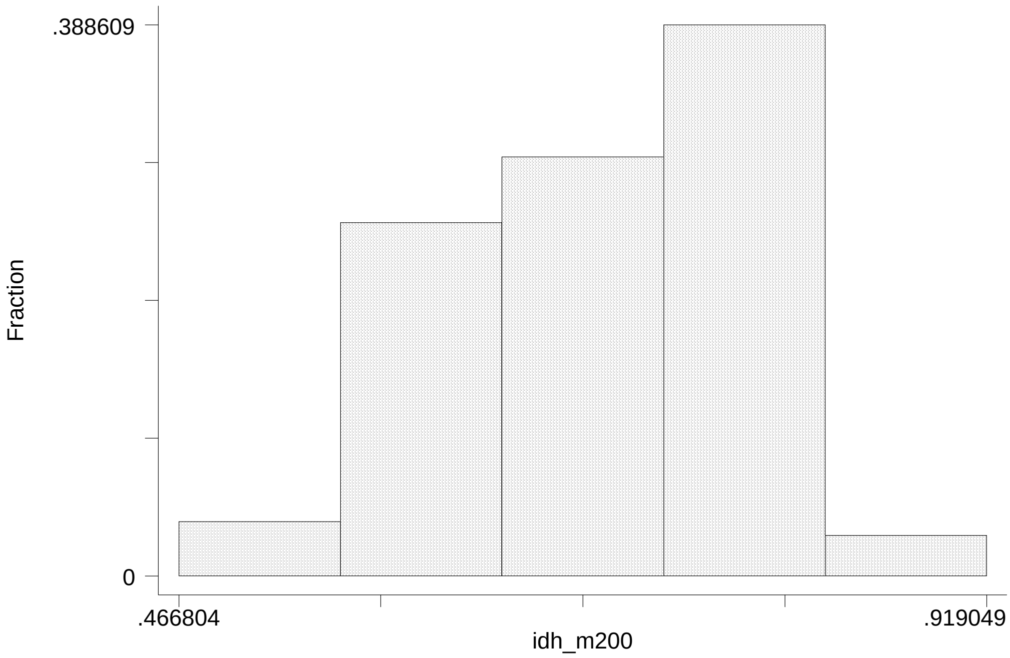
[10] As the intervals between the M-HDIs are infinitesimal, when we use the variables in the continuous form, the coefficient will take on too high values for the variation of one unit in our dependent value.

observations[11]. So, in the first step of the estimation of the model (logistic model), the M-HDI variable is specified through these dummies, with the lowest M-HDI cities as reference cities, i.e., those with M-HDI level below 0.6.

Figure 2

Histogram I -Distributions of cities according to M-HDI intervals in 2000

Percentage of cities



M-DHI 2000

[11] The dummy variables are: did1 equals one in cities where M-HDI takes on a value below 0.60 and didh1 equals zero for the rest (663 observations); didh2 equals ne in cities where M-HDI takes on a value between 0.60 and 0.65 and didh2 equals zero for the rest (779 observations.); didh3 equals one in cities where M-HDI takes on a value between 0.70 and 0.725 and didh3 equals zero for the rest (779 observations.); didh4 equals one in cities where M-HDI takes on a value between 0.60 and didh4 equals zero for the rest (441 observations); didh5 equals one in cities where M-HDI takes on a value between 0.725 and 0.750 and didh5 equals zero for the rest (598 observations); didh6 equals one in cities where M-HDI takes on a value between 0.750 and 0.775 and didh6 equals zero for the rest (648 observations); didh7 equals one in cities where M-HDI takes on a value between 0.775 and 0.80 and didh7 equals zero for the rest (585 observations); didh8 equals one in cities where M-HDI takes on a value above 0.80 and didh8 equals zero for the rest (540 observations);

The results found for the first step of the model, which estimates the decision of registering a patent in the city reveal that there is a positive relationship between economic development and likelihood of patents registration. The high degree of adjustment of the model presenting pseudo R^2 equal to 0.4669 has come to our attention. The results found show that only for cities with M-HDI above 0.725 will the probability of registering patents differ from the cities with a worse degree of development. In this case, the probability of registering patents in this city increases fivefold. Always as the degree of development increases so does this probability.

TABLE 4

Patents Model – Logistic[12]

Variable description	Razão de chance	T
Favelas	2.8524	7.88
Incentives to economic activities	1.9888	3.81
Proger	0.8942	-0.73
Professional capability programs	1.2851	1.68
Internet Service Providers	2,3845	6.18
Existence of bookstores	1.5381	2.84
Number of Libraries	1.046	1.19
Number of daily newspaper	1.00	0.76
Date of municipal foundation	0.9687	-8.64
Didh2	0.1918	-1.43
Didh3	0.5220	-0.79
Didh4	0.9219	-0.10
Didh5	6.2698	2.93
Didh6	12.9976	4.23
Didh7	22.6645	5.17
Didh8	78.2168	7.17
Pseudo R2		0.4669

Source: prepared by the authors, based on IBGE (2002), INPI (2001), ISI (2000), IPEA (2002).

In addition, the presence of economic incentives, ISPs and bookstores contributes to the creation of patents. In the case of ISPs, the odds increases by 138% compared with cities that do not have such a resource, whereas the incidence of libraries increases by 50% the odds of having a registered patent. Although the existence of *favelas* may be a negative characteristic of economic development, it also indicates how urbanized the city is. Hence, the positive correlation found can be interpreted, not because the incidence of *favelas* leads to the generation of patents, but rather as an indication that the bigger the urban center, the greater the probability of the existence of patents. On the other hand, lack of statistical significance of the variable number of public libraries has drawn our attention, because we had expected it to be an important variable.

TABLE 5

Papers model – Logistic[13]

Variable description	Razão de chance	T
Favelas	2.0928	4.20
Incentives to economic activities	1.1045	0.42
Proger	0.9590	-0.20
Professional capability programs	1,3199	1.37
Internet Service Providers	5.607	8.00
Existence of bookstores	2.1795	3.04
Number of Libraries	1.2088	3.86
Number of daily newspaper	1.007	1.93
Date of municipal foundation	0.9848	-2.47
Didh2	0.5612	-0.57
Didh3	1.4524	0.46
Didh4	1.5157	0.49
Didh5	2.5917	1.23
Didh6	3.9690	1.86
Didh7	4.0578	1.88
Didh8	9.8131	3.14
Pseudo R2		0.3807

Source: prepared by the authors, based on IBGE (2002), INPI (2001), ISI (2000), IPEA (2002).

[12] The reference category is a city with its M-HDI inferior than 0,60, with no *favelas*, no bookstores, no professional capability programs, no employment and income generation programs and no Internet service provider.

[13] The reference category is a city with its M-HDI inferior or equal to 0,35, with no *favelas*, no bookstores, no professional capability programs, no employment and income generation programs and no Internet service provider.

Concerning the publication of papers (see table 5), the results are quite similar, except for the variables ‘incidence of incentives to economic activities’, ‘number of public libraries’ and ‘number of daily newspapers’. In this case, both the number of libraries and the number of daily newspapers are statistically significant, suggesting a difference in the paper writing process in comparison with that of patents. In the case of papers, this result is probably due to the need for intellectual critical mass density to places where there are research institutes and universities. Besides that, the magnitude of the coefficient estimated for the presence of bookstores in the paper publication model is higher than that estimated in the patent registration model, which can reinforce the interpretation about the role played by research institutions. As for the M-HDI variables, we have found that only from the didh6 dummy will the coefficient be statistically significant[14], which suggests that only in the cities with a development index higher than 0.75 do papers stand a chance of being published.

In the second step of the patent registration model, when we estimate the Negative Binomial truncated to zero, we do not use the dummies that portray the M-HDI scale among the cities. We do, however, use the index itself[15]. This specification of the variable is due to two reasons: firstly, the M-HDI specification through the dummy variables greatly increases the number of independent variables; secondly, the continuous variable specification admits direct interpretation in the case of Negative Binomial model. The results point to the statistical significance of the variables ‘incidence of *favelas’*, ‘incidence of ISPs’, ‘number of libraries’ and also the ‘M-HDI’. In this case, we have reported the coefficients estimated in Table VIII. For the binary variables, we have calculated anti log[16] in percentages and, for the continuous or discrete variables, the coefficient can be interpreted directly as a semi-elasticity (Cameron and Trivedi, 1988). The results corroborate those obtained in the first step: for those cities with *favelas*, the expected number of registered patents is 345% greater than that of the cities without *favelas*. As for Internet, cities with ISPs present an expected number of patents 206% higher than that obtained in cities without ISPs. The result obtained for the variable ‘number of libraries’ has drawn our attention, because it has become significant in the second process (i.e. definition of number of patents) whereas no statistical significance could be found in the first one . The presence of an additional library implies that the expected number of patents

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[14] The coefficients are significant at 6% level.
[15] We have also run the model using the M-HDI specifications, but the coefficients are not significant. This result is probably due to the intervals chosen. As the number of cities with positive registration of papers and patents is very low, we have chosen to present only the continuous, M-HDI specification.
[16] The anti log is calculated by (expβ-1)*100

will increase by 20%. Furthermore, an improvement in the M-HDI in one unit tends to increase the expected number of patents[17] by 1000%.

TABLE 6

Patents model: Negative Binomial truncated to zero[18]

Variable description	Coefficients	T
Favelas	1.4939	6.62
Incentives to economic activities	-0,1583	-0,45
Proger	-0,0505	-0.02
Professional capability programs	0,4964	1,85
Internet Service Providers	1.1199	4.15
Bookstores	0,2450	0.81
Library	0,2092	2,68
Daily newspaper	0,0263	0,92
Date of municipal foundation	-0,0117	-1,26
M-HDI	10,3461	3,81
Constant	-17,2315	-1.30
Pseudo R2	0,0697	

Source: prepared by the authors, based on IBGE (2002), INPI (2001), ISI (2000), IPEA (2002).

In the Negative Binomial model for papers (see Table 7), only the variables ‘number of public libraries’, ‘presence of bookstores’ and ‘M-HDI’ are significant at 5% level. Although the level of significance is not the same as in the logit model (first step), the variables of culture infrastructure remain as determinants of the expected number of published papers. The presence of more than one library in the city generates an expected 16% increase in the number of papers.

[17] The M-HDI ranges from 0.4668 to 0.9190, with an average of 0.7 and standard error of 0.081. There is no direct interpretation for the meaning of the variation of one unit in the M-HDI. In the dummy model human development is not statistically significant in the second steps of the models.

[18] The model converge after 14 interactions, however the function no hollow and this manner we can’t conclude that the function converge at a point of worldwide maximum.

TABLE 7

Papers Model: Negative Binomial truncated to zero[19]

Variable description	Coefficients	T
Favelas	0,3641	0,81
Incentives to economic activities	-0,6424	-0,85
Proger	0,4626	0,55
Professional capability programs	0,5747	0,65
Internet Service Providers	-1,2550	-0,82
Bookstores	1,6398	2,05
Library	0,1646	2,82
Daily newspaper	-0,0104	-1,29
Date of municipal foundation	-0,01932	-1,09
M-HDI	12.7316	2,87
Constant	-16.1470	-6,56
Pseudo R2	0,0496	

Source: prepared by the authors, based on IBGE (2002), INPI (2001), ISI (2000), FJP (1997).

5 Estimating the simultaneous determination of technology, human development and economic growth

Recognizing the limitation of the analysis carried out in section 4, we aim at considering the more complex and multifarious connections between technology and human development in this section. Using the frameworks proposed by UNDP (2001) and Bernardes and Albuquerque (2003) as our departure points, we propose a simultaneous equations model so as to contemplate the mutual causal links between these dimensions.

5. 1 Treatment of the variables

Once data has been organised for the year 2000, we first estimate a cross-section model. It permits the assessment of unilateral connections between human development, technology, economic growth and science. In order to investigate reciprocity relations among these variables, it will be conducted the Hausman Test for simultaneity and the model will be estimated by means of a simultaneous equations model.

[19] The model converge after 24 interactions, however the function of maximum likelihood is no hollow and this maner we can’t conclude that the function converge at a point of worldwide maximum.

Before performing the estimations, it is necessary to present the adaptations and normalizations of the variables. First, the statistics of patents and articles are divided by the total population of the city, as recommended by the literature (BERNARDES; ALBUQUERQUE, 2003; SILVA, 2003. Second, in order to seize the isolated effects of economic growth on human development and on technology production, we have chosen to break up the M-HDI into its three sub indices (income, education and longevity). This division entails theoretical motivations, since it is expected that technical progress have effects on human capabilities directly and indirectly through economic growth (UNDP, 2001). Hence, MHDI_Income was used as a measure of economic growth and a combination of MHDI_Education and MHDI_Longevity as a proxy of human development[20]. All variables were standardized in natural logarithm.

For the cross-section estimation, we have as endogenous variables technology, economic growth and human development for the year 2000 and as exogenous papers (2000) and lagged human development ($HDIel_{1991}$). It should be emphasized that science is put here as an exogenous element in the system due to theoretical and statistical motivations. Theoretically, it is expected that, in immature systems of innovation, the connections between technology and human development towards science have not been fully established and that scientific production be a result of a collective decision (i.e. public policies), being classified as a decision variable (SILVA, 2003, p. 73). Statistically, it has not been found for this sample any significant effect either of technology or of human development on science.

5.2 Model specification

Figure 3 summarizes the model proposed, describing the set of mutual causal links among technological production, human development and economic growth. The blue arrows come from UNDP's scheme (2001), whereas the red ones were added in this work, inspired by the arguments of Bernardes and Albuquerque (2003). The dotted arrow indicates that no sufficient evidences were found in this work to support it, whereas the empty one designates a

[20] O cálculo dos sub-índices já se encontra disponível no Atlas de Desenvolvimento Humano do Brasil. Eles são estimados separadamente, em índices parciais, cujos valores variam entre 0 e 1. A fórmula geral para a construção desses índices é:

$$Índice = \frac{valor\ observado - valor\ mínimo}{valor\ máximo - valor\ mínimo}$$

Note-se que os valores limites são parâmetros estáveis da UNDP.

Com base nos valores observados para o país ou região em questão, calculam-se os índices de Longevidade, Educação, e Renda. Para este trabalho, os índices de longevidade e educação foram combinados na forma de uma média aritmética simples. Deve-se notar que, por construção, estes sub-índices são independentes, o que nos permite combiná-los diferenciadamente.

theoretically expected relationship to which no econometric evidence was found. 'Others' refer to the vast set of factors associated with economic growth besides science and technology, such as availability of natural resources, growth of the work force, among others. It appears on figure 3 because it holds significant importance in immature countries.

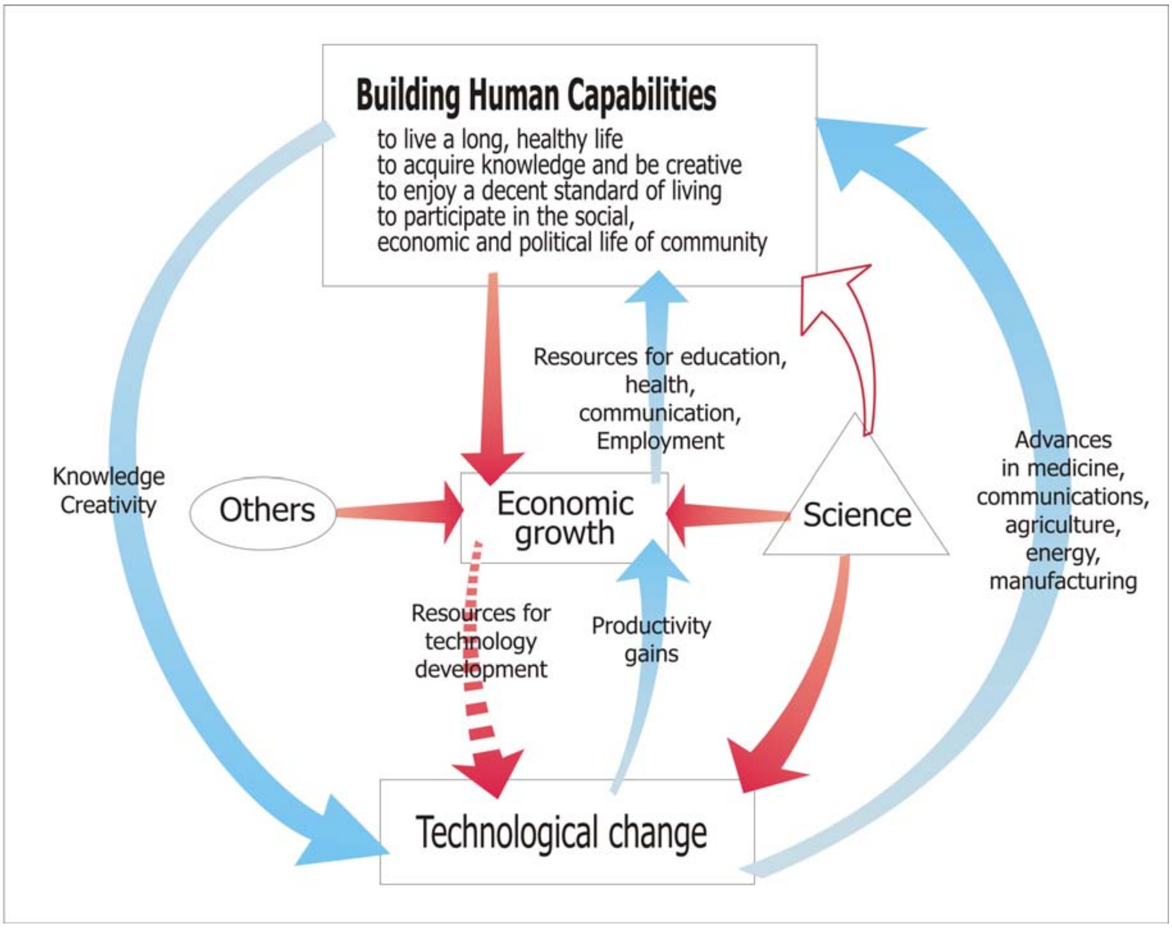

FIGURE 3
Patterns of interaction between Science, Technology, Human Development and Growth in Immature Systems of Innovation
Source: Araújo (2005)

So there follows the equations proposed in this model:

$$e_1 \quad \ln HDIel_{i,2000} = \alpha_0 + \alpha_1 \ln P^*_{i,2000} + \alpha_2 \ln HDIr_{i,2000} + \varepsilon_{i,t}$$

$$e_2 \quad \ln HDIr_{i,2000} = \beta_0 + \beta_1 \ln P^*_{i,2000} + \beta_2 \ln A^*_{i,2000} + \beta_3 \ln HDIel_{i,1991} + \upsilon_{i,t}$$

$$e_3 \quad \ln P^*_{i,2000} = \delta_0 + \delta_1 \ln A^*_{i,2000} + \delta_2 \ln HDIel_{i,2000} + \nu_{i,t}$$

in which:

$HDIel_t$: Municipal Human Development Indicator combined of Education and Longevity

$HDIr_t$: Municipal Human Development Indicator of Income

P^*_t: Patents per capita (in millions of people); A^*_t: Papers per capita (in millions of people)

i = unities of *cross section* (in this work, they represent the cities);

5.3 Main results

Table 9 shows the results related to the *cross-section* estimation of the set of equations (1-3) through ordinary least squares (OLS)[21].

These results bring about some important evidences. The first equation reveals that, for the sample analysed, technical progress and economic growth are significant to explain human development. Nevertheless, the White Test to heterokedasticity suggests the rejection of the null hypotheses at the level of significance of 5% (p-value: 0,0014), what invalidates the significance tests taken from the OLS estimation (GUJARATI, 2000). This problem was corrected through the White matrix and the equation was once more estimated by means of the Generalized Least Squares method (GLS) – e_1_b. All the coefficients were significant and showed the expected signals.

TABLE 9
Econometric results from OLS Estimation (equations 1,2 and 3)

Equation	Coeff.	Value	P >|t|	R^{2adj}	White Test (p-value)	VIF (average)
e1	α_0	-0,137	0,0000	0,505	0,0014	1,84
	α_1	0,010	0,0020			
	α_2	0,267	0,0000			
e1_b[i]	α_0	-0,137	0,000	0,505	-	1,84
	α_1	0,010	0,006			
	α_2	0,010	0,006			
e2	β_0	-0,181	0,0000	0,687	0,6886	1,43
	β_1	0,019	0,0001			
	β_2	0,007	0,0080			
	β_3	0,744	0,0000			
e3	δ_0	5,749	0,000	0,406	0,6757	1,03
	δ_1	0,138	0,012			
	δ_2	16,11	0,000			

Source: Author's elaboration
Note: ([i]) Equation 1 estimated through GLS with correction to heterokedasticity

Furthermore, it is important to emphasize the lack of the variable 'scientific papers' in this equation, which has not demonstrated any significant effect on human development[22]. Theoretically, it was expected that advances in science would increase welfare. For instance, in the health sector, a scientific breakthrough can increase life quality and expectancy once it provides more knowledge about the functioning of human body or a new drug or treatment.

[21] The estimations were performed through the softwares *Intercooled Stata 8.0* and *E-views 4.1*.
[22] This result contradicts, to a certain extent, the data presented on table 4, in which cities with scientific production have higher human development indicators. We suspect that the high variance of this variable makes it not significant.

There are many arguments that can justify this finding. First, one can affirm that advances in scientific knowledge does not necessarily imply on improvements on welfare, since it depends on the processes of knowledge flows and on the interactivity inside an innovation system, i.e., from the academic community towards the different actors. These flows can be more or less efficient. Second, one has to keep in mind that we are dealing with an immature innovation and welfare system, in which the interactivity among agents is still deficient. Only an international comparative study could elucidate this point. Third, it may lay here a qualitative question that refers to the orientation of scientific advances – to where is science going? To whom does it intend to serve? What are the orientations of the academic community and of public finance? These are issues that emerge from this debate and that may lay behind this result, but that are beyond the limits of this work. Finally, it might exist a question of spatial localization, once scientific advances that show effects upon welfare conditions do not necessarily happen in the same city.

The second equation displays evidences that not only technical progress influences economic growth – in accordance with UNDP's arguments – but so does science, as Bernardes and Albuquerque (2003) point out. The variable 'human development' lagged turned out to be significant, suggesting, although cautiously, that it exists a missing arrow in FIG. 1 – from human development towards economic growth. Besides, for this estimation we do not reject the null hypotheses of homecedasticity at 5%, following White Test (p-value: 0,6886)

The equation 3 puts technology as a function of science and of human development. Nevertheless, we do not find indications that income has a substantial impact on technological activity. If, on one hand, this finding contradicts UNDP's (20001) scheme, on the other it reaffirms the characteristics of regime 2 (immature systems of innovation) proposed by Bernardes and Albuquerque (2003). According to these authors, it is not expectable feedback mechanisms between these two dimensions for countries belonging to this group. We do not intend here to affirm that the theory supporting UNDP's framework is misleading, but rather that it needs special attention when dealing with underdeveloped countries like Brazil, where not all connections are fully established or strengthened. In this equation, White Test also does not suggest the rejection of the null hypothesis of homecedasticity (p-value: 0,6757).

The VIF statistics (Variance Inflator Factor) was also shown on TAB.9 in order to investigate for potential multicolinearity problems, specially between the variables scientific papers and human development (HDI_{el}). However, this problem was not detected, once VIF was much smaller than 10 on average (GUJARATI, 2000, p.337). There are important theoretical explanations for this result. Certainly scientific production is correlated with the general level of schooling of the population, in particular with higher education. Nonetheless, it depends on a set of other factors, overall on public investments. That is, even if Brazil could increase the number of enrolled students at all levels, its production of papers could only increase if more resources were allocated to research projects. In this manner, the insertion of both variables in the same side of equations 2 and 3 is justified.

The next step following the estimation of multiple regressions was the conduction of the Hausman Test for simultaneity (GUJARATI, 2000). It was found the presence of simultaneity between equations 1 and 2, 1 and 3, as well as between 2 and 3. The presence of endogeneity between these variables was thus confirmed. Above all, the most striking revelation was the detection of reciprocity between human development and technical advance in the sample of Brazilian cities for the year 2000.

These findings point out to the existence of a simultaneous equation system. As endogenous variables, we have human development (HDI_{el}), income (HDI_r) and patents for the year 2000. The exogenous variables are papers (2000) and lagged human development (HDI_{el91}). As instruments, we used the lagged variables of patents and income (P^*_{99} e HDI_{r91}). It was examined the identification conditions of this system through the order and the rank conditions. Two equations were classified as over identified (e_1; e_3) and one as exactly identified (e_2). Therefore, we have opted to use the Two-Stage Least Square Method (2SLS) for the estimation of this system. Results are organised on table 10.

TABLE 10
Econometric Results from 2SLS Estimation (n=113)
Instruments: $\ln HDIr_{i,1991}; \ln HDIel_{i,1991}; \ln P^*_{i,1999}; \ln A^*_{i,2000}$

Equation	Coeff.	Value	$P > \|t\|$	R^{2adj}
e1	α_0	-0,175	0,0000	0,489
	α_1	0,016	0,0013	
	α_2	0,210	0,0017	
e2	β_0	-0,263	0,0000	0,657
	β_1	0,0337	0,0000	
	β_2	0,0054	0,0640*	
	β_3	0,5884	0,0000	
e3	δ_0	6,298	0,0000	0,395
	δ_1	0,1258	0,0222	
	δ_2	18,972	0,000	

Source: Author's elaboration
Note: (*) Significant at 10%

It is important to emphasize that all variables showed expected signs and were significant at the level of significance of 5% (with exception of β_2, at 10%). The coefficients designate the elasticity between the variables.

6 Preliminary Conclusions

This study is an initial effort for a more comprehensive evaluation of the complex relationships between scientific technological production and welfare. This article's contribution lies in the statistical evaluation carried out on a municipal level and in the use of available data on science, technology and welfare.

Three preliminary conclusions can be distinguished:

- Firstly, there is a strong relationship between cultural infrastructure and scientific technological production;
- Secondly, there is a complex association between scientific technological production and welfare data. The results of the tests carried out indicated the scientific technological production is associated with human development indicators;
- Thirdly, there is the puzzle of the correlation between *favelas* and the production of papers and patents.

How should we understand these conclusions?

The direct and clear association between cultural infrastructure data (libraries, newspapers, Internet) and technological development is not a difficult one to understand. Certainly, the availability of that type of resources is a pre-condition for scientific technological production.

The second and the third conclusions seem to be in contradiction.

On the one hand, the spatial distribution of science and technology activities somehow follows the Brazilian map of regional concentration of income and economic activities. So, obtaining an HDI that corresponds to that of a country with "high human development"(IDH > 0.8) has such significant effects on the probability of identification of scientific technological production in a city.

On the other hand, the statistical correlation between science and technology production and *favelas* identifies a point that has been put forward by Celso Furtado: the polarization "modernization-marginalization" is a feature of underdevelopment (Furtado, 1987). Wealth (for a minority) and poverty go hand in hand. Therefore, there is the geographical co-localization of modern labs and *favelas* (as section 4 points).

Furtado contributes to the UNDP elaboration as he points the non-linear process that is necessary to overcome underdevelopment. More than the quantitative growth is necessary. Furtado emphasizes that “development in Brazil today is essentially the solution of the social problem” (2003, p. 14). And he emphasizes the combination of “social homogeneity” with “the creation of an efficient productive system, endowed with relative technological autonomy” as an Eastern Asian lesson for overcoming underdevelopment (1992).

The issue is how to break social perverse features that feeds the “modernization-marginalization” process. The answer may be in a institutional co-evolution: the combined formation of innovation systems (Nelson, 1993) and welfare systems (Esping-Andersen, 1990). To overcome the polarization modernization-marginalization, a combined construction of innovation and welfare systems can be a public policy long-range goal. Underlining this combined institutional building, there is a theoretical elaboration on the positive feedbacks between efficiency and growth (NSIs) and equality (Welfare Systems).

How this combination could take place?

From the welfare system to the NSI: 1) the main links are straightforward: a- nutrition and health: basic condition for education and work; b- education: contributing for learning by doing, prerequisite for activities of a knowledge-based economy; c- work conditions (safety, healthy environment, accidents prevention, reduction of working hours, etc): productivity improvements, learning by doing, problem shooting, workers' involvement in technical change; furthermore, 2) Reduction of unemployment, internal market expansion, and division of labor.; and 3) Welfare institutions mitigating "friction" in the labor market due to technical change: a- during a catching up process, technical progress may destroy some occupations and demand new ones (labor training and retraining would be necessary); b- Welfare institutions might establish "flexibility" (workers mobility) without high social costs: this would reinforce a precondition for a more dynamic society, allowing a permanent process of "labor repositioning" pushed by technological revolutions.

From the other direction, the NSI improving welfare conditions: 1) In general: output and productivity growth are sources of welfare improvements; 2) Technical progress as a tool for improvement in labor conditions (priority for automation of working places that causes occupational diseases, for example); 3) scientific community as "focusing device": definition of targets that are "country-specific" (for example, biotechnology development combined with medical research about prevalent diseases, etc). 4) "Mission-oriented" projects: defined in terms of economically feasible technical solutions to particular social problems (as suggested by Freeman, 1996, to particular environmental problems).

These conclusions, preliminary, as they may be, can foster discussion of some suggestions for public policies;

1. Investments for nationwide expansion of scientific technological infrastructure, so as to mitigate its high regional concentration (only 204 cities published at least one indexed paper in 1999 and only 494 cities have institutions that filed at least one patent between 1988 and 1996): a less concentrated distribution can be a way for that infrastructure to handle the diversity of existing problems in the country reaching cities with lower M-HDI, for example;
2. Strengthening of the cultural infrastructure: an important requirement for scientific technological production, and which as demonstrated in the study, influences scientific technological production;
3. As suggested by the theory and several evidences have been gathered, social advances do have an impact on scientific technological production, whether by health improvements (with impacts on learning capabilities) or reduction in the illiteracy rate and educational improvement;
4. As for the scientific technological infrastructure, two other movements can be made: first, an expressive increase in the resources available to the sector (a requirement for the necessary accumulation of critical mass to engaged a positive impact of the scientific technological activities on living conditions); second, a better application of the existing resources towards meeting such social priorities as health, housing and living conditions in great urban centres. With that in mind mission-oriented projects can be formulated, as suggested by Freeman (1996), for environmental conditions;
5. Last but not least, to overcome the polarization modernization-marginalization, the combined formation of a national innovation system and a welfare system is the main goal. This combined institutional goal may overcome in a co-evolutionary way, the technological and social gap present in the Brazilian economy.

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