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# National Systems of Innovation and Non-OECD Countries: Notes About a Rudimentary and Tentative "Typology"

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This paper suggests a tentative "typology" for Non-OECD National Systems of Innovation (NSIs). Three main categories compose this tentative "typology": "mature" NSIs, catching up NSIs, and "non-mature" NSIs. This paper investigates theoretical mediations which may be necessary if the NSI concept is to be applied appropriately to Non-OECD countries. Science and technology statistics are used to evaluate the suggested "typology". Basic statistics (GDP, R&D expenditures, education, patents, and papers) are presented. Data from forty-six countries are used for statistical exercises. The findings of this paper hint that it is possible to cluster different countries around science and technology indicators.

## I. INTRODUCTION

National System of Innovation (NSI) is an important concept and a useful reference for the discussion of the technological dynamics of different countries. But it can not be used to discuss Non-OECD countries uncritically.

This paper suggests a tentative and rudimentary "typology" of NSIs, focusing especially Non-OECD countries. This tentative "typology" clusters various countries around science and technology indicators and anecdotal evidence. This "typology" is a contribution to an evaluation, in particular, of the status of the Brazilian NSI.

The starting points and theoretical background of the rudimentary and tentative "typology" are: 1) Nelson's (1993) description of NSIs diversity; 2) Freeman's

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(1995) discussion of the distinct characteristics of some NSIs (Japan, former USSR, East Asian NICs, and Latin American countries); 3) Patel & Pavitt's (1994) suggestion that NSIs should be measured and might be compared.

Data from 46 countries are introduced, and statistical exercises are performed.

This paper is divided into seven sections. Section II presents the tentative NSIs "typology". Section III displays general characteristics of "ideal types" NSIs. Section IV discusses the role of science at the capitalist periphery, and suggests an "opportunity taking indicator". Section V performs a statistical test, investigating the cross-country correlation between R&D expenditures and patents granted by the USPTO. Section VI performs a second test, investigating correlation between R&D and scientific papers. Section VII concludes the paper.

## II. NON-OECD NSIs AND A RUDIMENTARY, TENTATIVE "TYPOLOGY"

The starting point for a tentative "typology" is a dividing line between OECD and Non-OECD countries: "catching up" NSIs. Catching up NSIs constitute a "transitional" category. Three broad sets of NSIs could be suggested: 1) "catching up" NSIs, as a dividing line; 2) ahead of "catching up", the "mature" NSIs (the majority of OECD countries); 3) behind of "catching up", the "non-mature" NSIs (Albuquerque, 1996, 1997).

Freeman (1995) provides anecdotal evidence for, at least, four types of NSI. First, he compares the main characteristics of NSIs of Japan and former USSR; second, the characteristics of successful East Asian NSIs are contrasted with Latin American stagnant NSIs.

Bell & Pavitt (1993) describe major differences between developed and developing countries. They go further, dividing the latter between the East Asian (Korea and Taiwan) and Latin American cases.

Pavitt (1997) describes major features of former "socialist" countries' systems of science and technology. He identifies a case of "obsolete competence". Radosevic (1997) compares the systems working under "socialist" regimes and their current transition to market economies.

This short survey presents cases that are compatible with the three categories of NSIs. In addition, this survey presents support for further differentiation within the general "non-mature" category earlier suggested. Three points can summarise these observations.

First, Freeman (1995) description of Japan, and Bell & Pavitt (1993) discussion of developed countries confirm general characteristics shared by the "mature" NSIs (OECD countries).

Second, Freeman (1995) and Bell & Pavitt (1993) stress the special case of East Asian countries, presenting major characteristics of catching up NSIs. Both papers provide support for a clear demarcation from catching up NSIs both from "mature" NSIs and from Non-OECD countries like Latin American. These two observations summarize support in the literature for the initial two major divisions suggested here:

1) catching up NSIs, the dividing line; 2) and ahead of catching up, "mature" NSIs.

The third observation introduces a division within the set of NSIs behind catching up: the "non-mature" NSIs. Non-mature NSIs involve at least two other sets of countries: a) Latin American countries (Freeman, 1995; Bell & Pavitt, 1993); b) former "socialist" countries (Freeman, 1995; Pavitt, 1997; Radosevic, 1997).

However, the literature surveyed does not discuss cases of countries like South Africa, India, Malaysia, Philippines, Nigeria, Pakistan, China etc. This demands further discussion and differentiation within the "non-mature" NSIs.

India and South Africa share some characteristics with Latin American countries. Bell & Pavitt, for example, point a characteristic that clusters India together with Latin American cases (but not with East Asian countries): weak "intra-firm technological accumulation" (1993, p. 194). India and South Africa are countries that can be classified as "semi-industrialized" economies (as Latin American countries). They share with Latin American economies some characteristics described by Freeman (1995): the existence of a scientific infrastructure (universities, research institutes, and governmental agencies); weak commitment of business firms to innovative investments; presence of educational skills, but with problems and serious flaws. In the last decades they have also shared low levels of economic growth. The suggestion, then, is to cluster India and South Africa together with Latin American countries. This category could be labelled "old and ineffective science and technology structure" (henceforth OISTS NSIs).

The former "socialist" countries have common features, many inspired by the USSR model. However, China can not easily be fitted in this category. Although China is discussed as an economy in transition "from plan to market" (World Bank, 1996), it has important differences. First, China's recent trajectory displays a growth trend, whereas the other former central-planned economies have a declining trend. Second, the main economic characteristics of the transitions are broadly different: so far, China's introduction of market mechanisms has been more controlled. This short discussion suggests that the former European "socialist" countries should be grouped in a category, without China. This category could be labelled "Eastern and Central European Countries" (henceforth, ECEC NSIs).

Malaysia, Philippines (and other countries of Southeast Asia) are Non-OECD countries that are behind catching up and differ from the two latter categories (OISTS and ECEC NSIs). They also differ from countries like Nigeria, Pakistan. They have some characteristics that can be identified as "beginnings" of a NSI: literacy levels, educational improvements, some recent scientific and technological investments etc. As well as their economic growth, these improvements are recent. Discussing high-tech industries, Porter et al. (1996, p. 10) cluster the so-called "Asian cubs" together. The suggestion is to put together Malaysia, Thailand, Indonesia and Philippines in a category labelled "Asian cubs" NSIs.

Other countries (Pakistan, Nigeria, Turkey, for example) are difficult to group with the categories suggested in this section. Probably, some would be labelled as "non-existent" NSI. To avoid discussions complex and beyond the subject of this paper, the remaining Non-OECD countries will be labelled as "others". Moreover, this label stresses the limits of the "rudimentary" NSI typology suggested by this paper.

Thus, the short survey presented in this section plus the discussions of some groups of Non-OECD countries lead to a four-category rudimentary and tentative "typology", with one category ("non-mature" NSIs) divided in three sub-categories. The 46 countries of the sample used in the next sections are distributed by these categories:

1) "Mature" NSIs: Belgium, Denmark, Germany, France, Ireland, Italy, Netherlands, United Kingdom, Austria, Switzerland, Canada, United States, Japan, Australia, New Zealand, Israel;

2) Catching up NSIs: Korea, Taiwan, Singapore (for 1992, only);

3) "Non-mature" NSIs:

a) "Non-mature" OISTS NSIs: Mexico, Argentina, Brazil, Chile, Venezuela, India, South Africa, Greece, Spain, Portugal (Korea, Taiwan, and Singapore, for 1981);

b) "Non-mature" ECEC NSIs: Russia, Bulgaria, Czechoslovakia, Hungary, Poland, Romania;

c) "Non-mature" "Asian cubs" NSIs: Indonesia, Malaysia, Philippines, Thailand;

4) Others: Turkey, China, Pakistan.

Statistical tests performed in next sections adopt this classification.

## III. BASIC SCIENCE & TECHNOLOGY DATA AND STATISTICS OF "IDEAL TYPES" NSIS

Once the rudimentary and tentative NSI "typology" has been suggested, this paper gathers data and attempts to present measures and comparisons of these NSIs, using a methodological device proposed by Weber (1978): "ideal types". Some countries can be pinpointed as "ideal types" of their respective NSIs categories. Choosing a small number of countries, data for different characteristics of each NSI is gathered and can be compared.

This discussion has a very specific objective. It tries to investigate whether it is possible to cluster countries around basic S&T statistics. Put another way: are there differences between the categories that can be captured by S&T statistics?

Two sets of data are presented in this section (Table I, page 50; and Table II, page 51).

Table I displays thirteen selected economic and S&T indicators for five countries: United States ("mature" NSI); Korea (catching up NSI); Brazil ("non-mature" OISTS NSI); Russia (ECEC NSI); and Malaysia ("Asian cub" NSI). Each selected country is an "ideal type" of its respective NSI category.

Table II expands the sample, adding more three countries to each "ideal type". This helps to search for regularities among each NSI category. The NSIs categories are represented as follows: a) "mature" NSIs: USA, Japan, Germany, and Sweden;

b) catching up NSIs: Korea, Taiwan, and Singapore; c) "non-mature" OISTS: Brazil, Mexico, India, and South Africa; d) ECEC NSIs: Russia, Czechoslovakia, Hungary, and Poland; e) "Asian cubs" NSIs: Malaysia, Thailand, Philippines, and Indonesia.

To these five NSIs categories, data were gathered and averages calculated for each of the indicators selected. Table II shows the averages for the five categories for each indicator.

Tables I and II permit to organise some major characteristics of Non-OECD NSIs, according to their statistical data.

The data shown in Tables I and II point the possibility of clustering different countries around some basic S&T indicators. Each of these Tables intends to contribute to the discussion of this section in a different way.

Table I intends to show major statistical differences between "ideal types" NSIs, representing the five suggested categories of the rudimentary and tentative "typology" (for example: comparing USA, Korea, Russia, Brazil, and Malaysia, there is a decreasing trend in the share of GNP allocated to R&D activities).

Table II shows that there is some coherence within each of NSIs categories. As new countries are added to the "ideal types" presented in Table I, the resulting averages, in general, do not contradict the data presented in Table I. In general, the rankings presented to each indicator in Table I are not changed in Table II.

Using the data of Tables I and II, it is possible to describe some major (and distinctive) characteristics that permit the clustering of countries, in NSI categories, around the S&T indicators displayed therein. The data for USA and for "mature" NSIs are a general reference to the evaluation of other (Non-OECD) NSIs.

1) CATCHING UP NSIs: Probably, the most important information is the correlation between the increase in USPTO patents and their annual average growth rates. This is combined with the predicted closer figures of USPTO patents per head. Other important feature is the education data, which are similar to the "mature" NSIs. Also there is a closing gap in R&D and science & engineering indicators. Interestingly, the ratio "USPTO patents/Papers" is similar to "mature" NSIs' figures.

2) "NON-MATURE" OISTS NSIs: Contrasting with the catching up NSIs, there is a stagnant pattern. This pattern is highlighted by the correlation between the stagnant USPTO and average annual growth figures. Educational problems present (for instance, see the illiteracy figures). There is low level of R&D and science & engineering commitments. Business R&D performing a lower level of activities than in the case of catching up NSIs. The existent scientific structure shows some level of activity. Domestic patenting data also show some domestic innovative activities. The ratio "USPTO Patents/Papers" is lower than both "mature" and catching up NSIs.

3) "NON-MATURE" ECEC NSIs: The correlation between the decline in USPTO patenting and in economic growth is the most important trend. It contrasts with the two latter NSIs categories. This NSI category shows a good educational level. And it also displays the existence of important scientific resources (science & engineering data, papers published). Domestic patents hint some level of technological

activities. The high ratio between domestic and foreign patents suggests economies with low levels of diffusion of foreign technologies. Like "non-mature" OISTS NSIs, ECEC NSIs also has a low ratio "USPTO patents/Papers".

4) "NON-MATURE" ASIAN CUBS NSIs: Like catching up NSIs, they have a positive trend in USPTO patenting activities and in economic growth. But, like "non-mature" OISTS NSIs (and unlike catching up NSIs), they have low USPTO patents (and domestic patents) per head. There is a scientific infrastructure, which leads to levels of scientific activities (papers per head and science & engineering resources) similar to OISTS NSIs. Educational resources are important. They are not close to catching up NSIs, but their data are better than OISTS NSIs (see, for example, the illiteracy data). There is a high level of technological diffusion, measured by the ratio "domestic/foreign patenting" (this hints that a possible important difference within "non-mature" NSIs is the different pace of technological diffusion in their economies).

## IV. "OPPORTUNITY TAKING INDICATOR": INVESTIGATING THE USEFULNESS OF NON-OECD SCIENTIFIC INFRASTRUCTURE

This section introduces an "indicator" (OTI) to provide some hints about the relationship between scientific effort and industrial innovation in Non-OECD NSIs. It also provides some information about interactions between different component parts of NSIs.

To introduce the empirical examination of this "indicator" (OTI), an initial diversion from the empirical content of this section must be done. First, because it is necessary to specify what is the role of science at periphery. Second, because the "indicator" should be explained. Third, because the "intuition" behind the "indicator" (OTI) needs to be explained. After these three steps, the empirical data may be evaluated, and the results included in the description of Non-OECD NSIs (including catching up NSIs).

First, the role of science at periphery as a "focusing device" for the catching up process.

There is an extensive literature discussing the complex and multifarious interplay between science and technology (Rosenberg, 1976; Pavitt, 1991; Dasgupta & David, 1994). Nelson & Rosenberg (1993) summarise this relationship, stressing the role of science both as a "follower and leader" (and indicate the growing weight of science for modern economic growth).

Surveying this literature, at least five major contributions of science to technologic innovation in developed (OECD) countries can be pinpointed: a) source of technological opportunities; b) source of trained researchers; c) development of improved research techniques; d) development of instruments; e) source of tacit knowledge.

Regarding Non-OECD countries (the periphery), there are important differences in the role of science. Before and during a catching up process, there is an interplay between science and technology (as in developed countries), but it is different. One difference, that also points a great difficulty, is the more severe budgetary constraint imposed on peripheral scientific development.

The main difference rests on the contribution of science to the catching up process. It acts as a "focusing device" in this process. Science at periphery is important to function as antenna for the creation of links with international sources of technology. In a catching up and in a "non-mature" NSI, scientific infrastructure provides "knowledge to focus search" (Nelson, 1982). Instead of being a direct source of technological opportunity, as in "mature" NSIs, at the periphery science helps to identify the opportunities generated abroad. In other words, the main role of science in the periphery is to plug the NSI in the international scientific and technological flows. The emergence of a "knowledge-based" economy (in more interconnected world) increases the importance of such contribution to the creation of "absorptive capability" (key to the catching up process).

Other important contributions of science to technology in developed countries are minimised in the peripheral context: a) the development of research techniques could be substituted by foreign university training; b) the development of instruments could be substituted by capital goods imports; c) trained researchers for certain areas could be supplied also by foreign graduate programmes.

The literature highlights other specific contributions of science at periphery: a) taking part of local technological accumulation (Bell & Pavitt, 1993); b) providing minimum public scientific information to take advantage of "windows of opportunity" (Perez & Soete, 1998).

So, the role of science at periphery does not fit in traditional models. The interplay between science and technology at the periphery indicates that since the beginning of a catching up process, investments should be made in the scientific infrastructure. As a "focusing device", this scientific infrastructure might have the capability to spot the avenues of technological development that are feasible in the backward country, given the international and national conditions. This means that scientific information is necessary even to advise where the entry is not possible. This is very important to less-developed countries with huge resource scarcity. "Blind search" might be wasteful.

Science is not a simple consequence of initial industrial and technological development. It is not a "natural consequence" of such process. On the contrary, science is a precondition of such development. As this development succeeds, it dynamically changes and upgrades the role of science and its interplay with technology.

If science has a role even before the process of catching up, the next step is to discuss how it could be measured. This measurement might contribute to the differentiation of NSIs.

Second: the explanation of the suggested "indicator", OTI. It is a ratio between two different world shares: 1) the country's share of world scientific publications, represented by ISI data (as a proxy for national scientific production); 2) the country's share of world patenting, represented by its share in USPTO patents (as a proxy for technological activities).

OTI is calculated dividing the share of world patents by the share of world papers. Of course, OTI has many statistical and methodological problems that the literature identifies in patent and scientific publication statistics. Probably, as OTI is a relationship between these already problematic indicators, it magnifies their respective problems.

Because of these magnified measurement problems, OTI can only be used as an auxiliary tool. It can only help to evaluate a relationship between patents and papers.

Third: the intuition behind the OTI. It is simple: given the complex relationship between science and technology, a comparison between two relative performances might indicate how well they are interacting.

Moreover, NSIs are institutional structures where different building blocks interact. If there is a big gap between key institutions like, for example, firms, universities and research centres, this means a low level of interconnectedness of its component parts.

Thus, OTI could be a useful device to provide clues about (some aspects of) the interplay between the scientific and technological dimensions of a NSI. Comparing the two shares (patents and papers) might provide this clue.

Regarding the rudimentary and tentative NSIs "typology", a conjecture would be done, presenting a "spectrum" of OTI values: a) "mature" NSIs might have the relatively more balanced shares, reflecting investments in both dimensions and a reasonable interaction between them; b) "non-mature" NSIs might have unbalanced shares, reflecting flaws in the interactions within the system (and resources allocated in a wrong and unbalanced way); c) catching up NSIs might have relatively higher OTI, given their success in absorbing technology generated abroad and in plugging the system in the international flows (the scientific infra-structure is an effective "focusing device").

After this diversion, the empirical evaluation can be introduced. Table I presents data that fits well with this conjecture. Data shown at row 9 (USPTO patents/papers), are the values for OTI. They show Korea with the highest OTI, followed by the USA. Brazil, Russia and Malaysia (representing "ideal types" of "non-mature" NSIs) display OTI values smaller than USA. Data from Table II do not present such clear picture: "mature" NSIs have a OTI greater than catching up NSIs. The figure for "mature" NSIs is deeply biased by the Japanese data: Japan maintains in its mature NSI characteristics of its successful catching up.

Table III (page 52) presents OTI results, calculated from data for the 46-country sample. OTI values are presented for the years of 1981 and 1992.

Table III shows OTI values that are compatible with the conjecture presented here. Taking the general average as a reference, it is possible to distinguish two major groups of NSIs: a) above the general average: for 1992, "mature" and catching up NSIs; for 1981, "mature" NSIs; b) under the general average: for 1981 and 1992, all "non-mature" categories. In addition, catching up NSIs has the higher average for 1992.

The main finding of this section is a new element for the identification of a catching up NSI (the dividing line for OECD and Non-OECD NSIs). An important improvement in the OTI seems to be part of the formation of a catching up NSI. The "intuition" putted forward in this section is compatible with the data shown by Table III. This point to an ascending trajectory in relation to the lower values found for "non-mature" NSI.

The differences between "non-mature" NSIs could be initially understood by the specific weights of the two components of the OTI ratio.

ECEC NSIs, as can be seen in Table I and II, have strong scientific resources and low openness to international markets. Furthermore, the anecdotal evidence (Pavitt, 1997; Freeman, 1995) points a low level of interactions between industry and research.

OISTS NSIs, have some scientific resources, but also have problems with connections between research activities and industry. An example of these weak interactions is the low commitment of business firms with R&D activities.

"Asian cubs" NSIs show an improving trend between 1981 and 1992.

These initial suggestions and evidences are a starting point for an evaluation of OTI. At least three points should be mentioned for further investigation: a) high OTI for catching up NSIs might be related to a big concentration of scientific resources in disciplines that support key industrial sectors (there is not a pattern of "dispersion" of scientific effort across a large range of scientific disciplines)[1]; b) the division between "non-mature" NSIs deserves closer attention; c) in the case of "mature" NSIs, an investigation about internal differences could explain ascending trajectories (like Japan, that preserves its catching up roots, and keeps high OTI), and declining trajectories (like United Kingdom, that has a declining OTI and a declining relative share in its scientific publications).

In sum, this section suggested an indicator, OTI, that contributes to differentiate NSIs, providing an initial evaluation of the interactions between scientific and industrial components of a NSI. Catching up NSIs have a higher OTI than the rest.

## V. R&D, PATENTS AND NSI CATEGORIES: HINTS DRAWN FROM A STATISTICAL TEST

This section investigates the relationship between R&D expenditures and USPTO patents. Performing cross-country comparisons, this section evaluates especially the R&D-patents relationship within the suggested categories of the tentative NSI "typology". The question here is whether or not this cross-country comparison contributes to the differentiation between NSI categories.

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[1] The Korean case, for instance, shows how its R&D resources, once allocated to scientific activities, were highly concentrated in certain scientific disciplines. While Korean share in world scientific publications was 0.29 in the period 1989-93, in disciplines like Materials Science its share was 0.97 (Braun et al., 1995).

Again, there are important measurement problems. Griliches (1990) surveys related problems. He proposes a "knowledge function" that, if critically evaluated, might be useful for the purposes of this section. This kind of function (R&D as an input, patent as output) is widely used in cross-firms and cross-sectors analyses. This "knowledge function", however, is built upon questionable assumptions. For instance: a) it does not capture important inter-sectoral differences in "propensity to patent"; b) it does not take in account the existence of other important "appropriation mechanisms" (lead times, first mover, trade secrets); c) it underestimate "informal" R&D and the role of minor mechanical improvements.

Cross-country comparisons have other problems: a) different national inter-sectoral composition of national industries; b) lack of reliable R&D statistics (especially for Non-OECD countries); c) different countries are at different stages of development (and have different NSIs), which means that the role of patent as an important "appropriation" mechanism varies widely; d) different levels of technological development mean different combinations of innovative activities (some countries concentrate in imitation and minor adaptations, where patents are not so important); e) regarding USPTO patents, countries have different trade relations with USA and international markets, having different "propensities to patent" in the USPTO. In sum, the problems with an R&D-patents function are not simple. This function captures only part of a much more complex picture, especially in cross-country comparison.

The statistical test that this section proposes takes into account these limitations and problems. It tries to elaborate a hypothesis suggesting relationships between: a) Griliches' function, and its limitations; b) technological characteristics of each NSI category, regarding especially the limitations of Griliches' function to capture aspects of each category.

The "intuitions" behind the hypothesis are:

1) "Mature" NSIs have significant R&D expenditures, and produce expressive figures of patented innovations. Complex interplay between R&D performed and industrial innovations may be captured here, indirectly. This category shares characteristics that are supposed to be captured by the relationship R&D-patents.

2) Catching up NSIs has growing R&D expenditures, intense use of international flows of technology and increasing business firms' commitment to innovative activities. Given the weight of their export-oriented industries, they have high propensity to patent in the USPTO. This category, regarding the relationship R&D patents, has a pattern similar to "mature" NSIs (see Tables I and II).

3) OISTS NSIs have a S&T infra-structure, and some level of R&D expenditures. But, given the lack of interaction between component parts of NSI, the weak commitment of firms to innovative activities, and the concentration of their technological efforts in imitative activities, it is unlikely that patent statistics capture these activities. Thus, the relationship between R&D and patents might be weaker than the latter cases.

4) ECEC NSIs had heavy R&D expenditures, but with a high proportion allocated to military purposes (with a weak spillover to civilian uses). The weak inter-

actions between industry and research, and the closed nature of their markets and lack of links with US and international markets contribute to weak USPTO patenting. Therefore, the relationship R&D-patents might also be weaker than in the case of "mature" and catching up NSIs.

5) "Asian cubs" NSIs have low levels of R&D expenditures, but also have an intense technological activity concentrated in sectors where patents are not important. The main characteristics of their innovative activities are not captured by the R&D-patents relationship.

These observations give rise to a hypothesis. Given the different NSI categories, given the differences in the capacity of the relationship R&D-patents to capture characteristics of innovative activities of each NSI, the hypothesis conjectures that: "mature" and catching up NSIs might have the better "performance" in the relationship R&D-patents. The differences of this relationship within "non-mature" NSIs are difficult to predict.

To test the hypothesis, the general cross-country relationship between R&D and patents granted by the USPTO (for 1981 and 1992) must be investigated. According to the literature, at the cross-section level it is likely to be a logarithmic relationship (Griliches, 1990).

This hypothesis, therefore, may be tested using a statistical exercise. If the hypothesis is correct, it is possible to use "dummy" variables to differentiate NSI categories, given the different R&D-patents relations.

If the hypothesis is correct, statistically this would mean different intercepts and/or different slopes in a regression equation. Therefore, "dummy" variables are introduced, to investigate the statistical significance of these differences in intercept and/or slope[2].

The regression equation to be run should therefore assume a "double-log" form, and include "dummy" variables for different NSIs categories. The test involves five groups (given the observations discussed earlier, "mature" and catching up NSIs are supposed to have similar performances, so they compose a single statistical category. The general form to be tested is:

(1) log(pat) = (D1 + D2 + D3 + D4) log(R&D);

Where: log(pat) = logarithm of number of patents granted by the USPTO,

log(R&D) = logarithm of R&D expenditures (ECU millions),

D1 = 1, if "non-mature" OISTS NSIs, and D1 = 0, otherwise;

D2 = 1, if "non-mature" "ECEC" NSIs, and D2 = 0, otherwise;

D3 = 1, if "non-mature" Asian cubs NSIs, and D3 = 0, otherwise.

D4 = 1, if "others", and D4 = 0, otherwise.

Table IV (page 52) reports the results.

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[2] Greene (1993, chapter 8) explains the uses of "dummy" variables as "one of the most useful devices in regression analysis" and a "convenient means of building discrete shifts of the function into a regression model".

To examine whether or not the R-sq. found in Table IV is due to other factors, the variables (R&D and patents) were normalised by population size. The results show a similar R-sq., and the variables (including "dummy" variables) are also statistically significant[3].

The results do not refute the hypothesis tested. Therefore, the qualifications presented to the R&D-patents relationship, and the clustering of countries around NSI categories is useful. The NSI "typology" affords the elaboration of testable hypothesis about some characteristics of technological activities. However, the limits and cautions presented in this section are important[4].

The results found in this section indicate at least one argument supporting the NSI "typology": the R&D-patents relationship varies according to the NSI categories.

## VI. R&D, SCIENTIFIC PAPERS AND NSI CATEGORIES

This section discusses the relationship between R&D and scientific production. Papers published, using the Science Citation Index (SCI, computed by the Institute for Scientific Information — ISI), are a proxy for this "scientific output".

The literature reports studies that test relationship between R&D expenditures and scientific papers. Teitel (1994) is an example.

This section suggests a hypothesis regarding this relationship, and performs a test to evaluate the hypothesis. As discussed in section V, each NSI category might show a different pattern of relationship, given their main differences.

1) "Mature" NSIs might have the better performance in the function R&D-papers because: a) the development of their scientific infrastructure; b) the feedback effects on science of a strong technologic dynamic (science as a follower, or, technology creating demands for scientific endeavour).

2) Catching up NSIs have the pressure of a developing technologic system upon their scientific infrastructure. And, as discussed in section IV, the functioning of their scientific infrastructure as a "focusing device", which depends on an increasing integration in international flows, contributes to a good performance in the relationship R&D-papers. This category, thus, has a pattern similar to "mature" NSIs.

3) "Non-mature" OISTS NSIs have a scientific infrastructure, but it is limited and uneven. Only few disciplines attain international standards, and are well connected with the international community. The interaction with technology is weak. This lessens the feedback effects (from industry to science), and diminishes the sci-

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[3] The results of these normalised regressions found differences, between the NSIs categories, of intercept, instead of slope. In other words, the "dummy" variables are significant for intercept. All variables are significant at 1% level. For 1981 and 1992, R-sq. respectively 0.898 and 0.876.

[4] It is important to stress that the tentative "typology" was not tested in this section. In fact, the "typology" afforded the formulation of a hypothesis about how R&D-patents differs between NSIs categories. This hypothesis was not refuted. This result contributes to the discussion of the NSI "typology", but does not provide direct support to it.

entific output. Budgetary constrains threaten the stability of research groups, and, again, affect the output. They are a combination of scarcity and waste in the use of resources for science. So, this category might have a lower performance in the relationship R&D-papers.

4) "Non-mature" ECEC NSIs have an important scientific infrastructure and world level science. There were huge investments in the scientific sector in these countries. Although the feedback effects are weak (as in OISTS NSIs), the allocation of resources to the scientific sector enables a good performance. But, the transition to market economy has impacted deeply their scientific resources. So, for 1981 data, this category might have a similar performance to "mature" countries (however, the reasons underlying this good performance are different from "mature" NSIs). But for 1992, a general shrinking of the scientific sector has taken place. The question is whether or not this shrinking was similar in input (R&D) and output (papers).

5) "Non-mature" Asian cubs NSIs have the smallest scientific infrastructure of this sample. Given the small investment in this sector, their performance might expected to be weak.

Therefore, the hypothesis of this section suggests a ranking for R&D-papers performance. To test this hypothesis, an exercise similar to section V is done.

The regression equation to be tested has a slight different form: now, an intercept coefficient (C) is introduced.

(2) log(papers) = C + (D1 + D2 + D3 + D4) log(R&D);

Where: log(papers) = logarithm of country's world share of scientific papers,

log(R&D) = logarithm of R&D expenditures (ECU millions),

C = intercept coefficient,

D1 = 1, if "non-mature" OISTS NSIs, and D1 = 0, otherwise;

D2 = 1, if "non-mature" "ECEC" NSIs, and D2 = 0, otherwise;

D3 = 1, if "non-mature" Asian cubs NSIs, and D3 = 0, otherwise.

D4 = 1, if "others", and D4 = 0, otherwise.

Table V (page 52) reports the results.

To examine whether or not the R-sq. found in Table V is due to other factors, the variables (R&D and patents) were normalised by population size. The results show a similar R-sq., and the variables (including "dummy" variables) are also statistically significant[5].

The hypothesis is not refuted for 1981 data. In 1981, "mature" NSIs have the best performance; ECEC NSIs have a performance similar to "mature" NSIs (the "dummy" variable is not significant); OISTS NSIs have a weaker performance than the two others; and "Asian cubs" ranked behind them.

[5] The regression normalised by population size found variables "dummy" for intercept (instead of slope, as in Table V). For 1981, R-sq. is 0.838; variables "dummy" for D1 and D2 not significant. For 1992, R-sq. is 0.838. D1 is significant at 5% level, and D2 is not significant. These results are compatible with Table V.

However, for 1992 the results are less clear. "Mature" NSIs have, again, the best performance. Again, ECEC NSIs (although impacted by the "transition" effects) have a performance similar to "mature" countries. But, OISTS NSIs also do not have a different pattern from both (their "dummy" variables are not statistically significant). "Asian cubs" NSIs keep a different pattern.

The reasons behind 1992 results may lie in the data tested. Table I (comparing "ideal types" countries) shows higher shares of R&D resources allocated to non-business uses in Russia and Brazil (row 2, Table I). These data hint a relatively greater share of resources allocated to "academic" research. If the data used in the regression could capture this aspect, probably the results might have been more similar to the hypothesis of this section. As the R&D input of "mature" NSIs should be around 30% to 50% of their total, ECEC NSIs should be 70% to 90%, and OITST NSIs around 80%, it may be expected that the relative performance of "mature" NSIs would improve (and NSI categories might be statistically more differentiated).

## VII. CONCLUDING REMARKS

This paper suggests a rudimentary and tentative NSI "typology". This "typology" might qualify the NSI concept sufficiently to adapt it to Non-OECD countries. The literature presents theoretical support for a differentiation between the OECD and Non-OECD countries. This paper suggests that catching up may be a dividing line. The formation of catching up NSIs should be the goal for backward countries.

Data about S&T indicators are gathered to evaluate the usefulness of the suggested "typology". Using the "typology" as a reference, some statistical tests are performed. Their results are not incompatible with the NSIs categories. The introductory and exploratory nature of this paper must be kept in mind. The complexity of NSIs can not be captured only by the few data analysed here. These data provide an introduction for the analysis.

To minimise these limitations and handicaps, further research is necessary in at least four areas: 1) the development of the theoretical background of the "typology"; 2) the broadening of the S&T indicators to provide more statistical evidence for the "typology" in general; 3) the improvement of the discussion of the differentiation within "non-mature" NSIs (highlighting, especially, a more general discussion about indicators of technology transfer); 4) the expansion of the number of countries examined, introducing cases of countries that do not have even the beginnings of NSI.

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TABLE I

Selected economic and S&T indicators, for countries representing "ideal types" NSIs (1992)

| INDICATOR | USA | KOREA | BRAZIL | RUSSIA | MALAYSIA |
|---|---|---|---|---|---|
| 1 GNP per capita (an.av.gr 85-94) | 1.3% | 7.8% | -0.4% | -4.1% | 5.6% |
| 2 R&D (% GNP) | 2.62% | 2.00% | 0.59% | 0.78% | 0.08% |
| 3 Business R&D (% total R&D) | 68% | 71% | 26% | 10% | 45% |
| 4 US patents per million pop. | 204 | 12.72 | 0.25 | 0.45(b) | 0.75 |
| 5 Growth US pat. (1992/1981) | 1.33 | 31.65 | 1.74 | 0.18(b) | 14 |
| 6 Dom. pat. per million pop. | 204 | 84.45 | 1.65 | 32.23 | 0.56 |
| 7 Domestic pat/ Foreign pat | 1.16 | 0.52 | 0.16 | 1.52 | 0.01 |
| 8 Papers per million pop. | 3,446.5 | 177.86 | 82.75 | 531.43(b) | 67.54 |
| 9 Patents (% world)/ Papers (% world) | 1.53 | 1.84 | 0.07 | 0.01 | 0.29 |
| 10 Illiteracy | a | a | 17% | a | 17% |
| 11 Secondary (% age gr., male) | 98% | 93% | NA | 84% | 56% |
| 12 Tertiary (% age group) | 81% | 48% | 12% | 45% | NA |
| 13 Scien.&Eng. per thousand pop. | 3.72 | 1.57 | 0.34 | NA | 0.30 |

Source: USPTO and WIPO (patents); *Scientometrics* (papers); World Bank (GNP and education); UNESCO (education); European Commission (R&D, Science & Engineering); Bell et al. (1995, Business R&D); Freeman (1995, Business R&D)

Notes: (a) less than 5%; (b) data for USSR; Papers: data for 1989-93

TABLE II
Selected economic and S&T indicators, averages for groups of countries representing NSIs categories (1992)

| INDICATOR | Mature | Catch.up | OISTS | ECEC | As.Curbs |
|---|---|---|---|---|---|
| 1 GNP per capita (an.av.gr 85-94) | 1.5%(1) | 7.0%(2) | 0.5% | -1.7%(3) | 5.5% |
| 2 R&D (% GNP) | 2.8% | 1.7% | 0.6% | 1.3% | 0.2% |
| 4 US patents per million pop. | 141 | 25.2 | 0.8 | 2.6 | 0.26 |
| 5 Growth US pat. (1992/1981) | 1.5 | 18.1 | 1.9 | 0.4 | 5.7 |
| 7 Domestic pat / Foreign pat | 4.2 | 0.52 | 0.17(7) | 3.5 | 0.03 |
| 8 Papers per million pop. | 3,078.5 | 655.4 | 131.6 | 700.7 | 45.0(8) |
| 9 Patents (% world)/ Papers (% world) | 1.49 | 1.17 | 0.12 | 0.09 | 0.34 |
| 10 Illiteracy (min) | a | a | 10% | a | 5% |
| 10 Illiteracy (max) | a | 9% | 48% | a | 17% |
| 11 Secondary (% age gr.,male) | 98% | 93%(5) | 62.3(6) | 82% | 47%(10) |
| 12 Tertiary (% age group) | 46% | 48%(5) | 13%(4) | 26% | 18%(11) |
| 13 Scien.&Eng. per thousand pop. | 3.3 | 1.4 | 0.21(7) | 1.4(9) | 0.15 |

Source: USPTO and WIPO (patents); *Scientometrics* (papers); World Bank (GNP and education); UNESCO (education); European Commission (R&D, Science & Engineering)

Notes: (a) less than 5%; Papers: data for 1989-93; (1) without Germany; (2) without Taiwan; (3) with Czech Rep; (4) without India; (5) for Korea; (6) without Brazil; (7) without South Africa; (8) without Indonesia and Philippines; (9) without Russia and Czechoslovakia; (10) without Philippines; (11) without Malaysia

TABLE III
"Opportunity taking indicator" (OTI), (means, standard-deviations, maximum and minimum), according to NSIs categories (1981, 1992)

| CATEGORY | N.OBS. | MEAN | ST-DEV. | C. VAR. |
|---|---|---|---|---|
| 1992 | | | | |
| General | 45 | 0.386 | 0.565 | 1.463 |
| Mature | 19 | 0.418 | 0.617 | 1.477 |
| Catching up | 3 | 0.641 | 0.697 | 1.087 |
| "Non-mature" OISTS | 10 | 0.070 | 0.080 | 1.141 |
| "Non-mature" ECEC | 5 | 0.079 | 0.107 | 1.346 |
| "Non-mature" Asian cubs | 4 | 0.336 | 0.398 | 1.183 |
| 1981 | | | | |
| General | 45 | 0.351 | 0.473 | 1.347 |
| Mature | 20 | 0.441 | 0.553 | 1.255 |
| "Non-mature" OISTS | 13 | 0.221 | 0.322 | 1.451 |
| "Non-mature" ECEC | 5 | 0.059 | 0.082 | 1.401 |
| "Non-mature" Asian cubs | 4 | 0.187 | 0.206 | 1.102 |

Source: National Science Foundation (1996), European Commission (1994), *Scientometrics*, SPRU database, author's elaboration

TABLE IV
Log R&D X Log Patents, regression results (1981 and 1992)

| Variables | 1981 | 1992 |
|---|---|---|
| log(R&D) | 0.833 (35.376) | 0.824 (34.165) |
| D1 | -0.377 (-8.827) | -0.371 (-7.476) |
| D2 | -0.267 (-5.085) | -0.333 (-4.769) |
| D3 | -0.665 (-8.520) | -0.450 (-8.746) |
| D4 | -0.719 (-9.520) | -0.590 (-9.520) |
| Standard Error of regression | 0.353 | 0.406 |
| N. observations | 44 | 45 |
| R-squared | 0.906 | 0.876 |
| Adjusted R-sq. | 0.896 | 0.863 |

Obs.: Numbers in parenthesis display t-statistics (the coefficients are statistically significant at 1% level, two-tail)
Source: European Commission (1994), National Science Foundation (1996), SPRU database and USPTO; author's elaboration

TABLE V
Log R&D X Log Papers, regression results (1981 and 1992)

| Variables | 1981 | 1992 |
|---|---|---|
| C | -2.420 (-11.390) | -2.665 (-10.795) |
| log(R&D) | 0.787 (12.170) | 0.806 (11.535) |
| D1 | -0.151 (-3.797) | -0.039 (-2.128)(*) |
| D2 | -0.027 (-0.587)(*) | -0.078 (-1.207)(*) |
| D3 | -0.453 (-6.266) | -0.199 (-2.052)(+) |
| D4 | -0.343 (-6.014) | -0.221 (-4.712) |
| Standard Error of regression | 0.304 | 0.272 |
| N. observations | 46 | 43 |
| R-squared | 0.873 | 0.844 |
| Adjusted R-sq. | 0.857 | 0.823 |

Obs.: Numbers in parenthesis display t-statistics (the coefficients are statistically significant at 1% level, two-tail; except when: (+) 5% level significance; (*) not significant)
Source: European Commission (1994), *Scientometrics*, author's elaboration