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(June 1997)

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Sumário

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 offers an initial investigation of the theoretical mediations which may be necessary if the NSI concept is to be applied appropriately to Non-OECD countries. The specificity of Non-OECD countries suggests that the concept of NSI needs important qualifications to be used in relation to those economies.

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 (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.

This paper is divided into two main parts. Part I surveys the literature, summarises some theoretical justification, and suggests a tentative and rudimentary NSIs typology. Part II presents some characteristics of "ideal types" NSIs, looks at the firm level, and performs statistical exercises.

Part I is divided into three sections. It begins with a survey of NSI literature, presenting the concept and the diversity among these systems (section II). Section III proposes a dividing line between OECD and Non-OECD NSIs, discussing catching up processes. Section IV presents the tentative NSIs "typology".

Part II is divided into six sections. It introduces data from 46 countries. Section V displays general characteristics of "ideal types" NSIs. Section VI looks at the firm level. Section VII discusses the role of science at the capitalist periphery, and suggests an "opportunity taking indicator". Section VIII performs a statistical test, investigating the cross-country correlation between R&D expenditures and patents granted by the USPTO. Section IX shows data of domestic patenting. Section X performs a second test, investigating correlation between R&D and scientific papers.

Section XI concludes the paper, evaluating the limits and handicaps of this initial, tentative and rudimentary "typology", stressing the necessity of further discussions and pinpointing issues for further research.

PART I: THE "TYPOLOGY" BACKGROUND

II. NSI: Concept, Diversity

Technological change is a major force of long-term economic growth (Dosi, Freeman & Fabiani, 1995). Therefore, how countries manage their technological dynamics is crucial to determine whether they will forge ahead, fall behind or succeed in catching up with leading economies.

Technological change is a product of a complex interplay of firms, inter-firms networks, universities, research institutes, professional societies, activities of an educated workforce, finance institutions, educational and informational infrastructure, government agencies, and public resources. This complex network of firms, institutions, and their interactions compose the "capitalist engine of growth" (Nelson, 1990). They feed the long term sources of economic growth.

This complex network has been described as National Systems of Innovation (NSI) (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Patel & Pavitt, 1994). This concept has received growing attention in the literature (Edquist, 1997, presents a recent survey).

The status of the concept of NSI (whether it is a theory or a conceptual framework) is beyond the modest scope of this paper. To achieve this paper's objectives it is enough to point that: 1) NSI is a concept that synthesises the neo-schumpeterian theoretical elaboration of the relationship between technical change, economic growth, and institutions; 2) NSI is a workable concept to pinpoint the limited understanding of mainstream economics of subjects like long term economic dynamics; 3) NSI describes the role of institutions, and institutional building (both intended and unintended) in economic growth.

Of course, NSI is a concept that needs and deserves further development, more precise theoretical foundations, and empirical support.

Using this concept as guideline, interesting comparative analysis have been done. Nelson (1993) is a major example. These comparative analysis have pinpointed one feature of NSIs: their diversity.

History is a major source of this diversity (Zysman, 1995). Institutional building and different national technological trajectories create systems of innovation with different characteristics.

The diversity among NSIs is a product of different combinations of their main characteristics. At least fourteen characteristics can be pinpointed:

1) Role of firms (the central unit of analysis of NSIs). There are cross-country inter-sectoral differences, different roles of large (and small) firms, and their connections.

2) Firms commitment to in-house R&D, as well as their capacity to finance it.

3) Role of public R&D institutions.

4) Relative weight of basic and applied R&D.

5) Relative weight of civilian and military R&D.

6) Presence and strength of spill-over from academic and military research towards civilian and business uses.

7) Degree of co-ordination (and the role of government in this co-ordination) among the constitutive institutions of the innovation systems.

8) Degree of centralisation and decentralisation within a national system (among institutions, regions, financing sources).

9) Role of financial institutions supporting the innovative investment.

10) Size of science and engineering resources.

11) Size and quality of educational institutions (general, vocational, universities).

12) Workforce qualifications, labour conditions.

13) Country's position in the international technological flows.

14) Relationship between technological performance and social conditions, in other words, relationship between NSI and the institutions of a welfare state.

Nelson (1993) presents rich anecdotal evidence of these major differences. It is possible to define a gradient of different positions in each of the former fourteen points.

Discussing the diversity among NSIs, Patel & Pavitt (1994) advance a step further: they highlight the challenge of measurement. They suggest that NSIs should be measured and might be compared. But, they point out, measurement of NSIs summarises all difficulties found in the issue of measurement of technological activities and technological change in themselves.

Pavitt & Patel (1996) measure and compare NSIs concentrating their evaluation in some key features as: 1) public support for basic research; 2) workforce skills; 3) business funded R&D; 4) systems of finance and management; 5) characteristics of competitive rivalry. Analysing these subjects, they identify a broad division within OECD NSIs: 1) "dynamic" (Japan, Germany); 2) "myopic" (USA, UK).[1]

So far, the majority of comparative studies (especially those with more detailed statistical cross-country comparisons) have concentrated on analysing differences of NSIs within OECD countries (for instance: Patel & Pavitt, 1994; Guerreri & Tylecote, 1997). This is understandable, given the deep "data constraint" that exists in relation to science and technology indicators outside OECD countries.

However, there is a major dividing line between OECD and Non-OECD countries. This dividing line is crucial to a careful extension of the NSI concept to Non-OECD countries. There are two main reasons for this.

First, although NSI can be defined as a set of firms and institutions, and the interaction between them, the Non-OECD case suggests that the mere existence of these entities does not mean, straightforwardly, the functioning of an effective, real, NSI.

Second, therefore, to discuss NSI in the capitalist periphery, it is necessary to establish mediations and qualifications. Summing up, to avoid inappropriate uses of the NSI concept, the case of Non-OECD countries needs important qualifications.

Henceforth, this paper deals with Non-OECD NSIs. It takes for granted that the whole OECD set constitute a different category of NSIs.[2] In the Section IV this set of NSIs will constitute a category identified as "mature" NSIs. This set of countries (the "mature" NSIs) has important differences within this category, but this discussion is beyond the scope of this paper.[3]

III. Benchmark for non-OECD economies: NSI for catching up

The process of overcoming a backward economic (and technological) position is not passive nor spontaneous. Even neo-classical scholars (Lucas, 1993) reckon the necessity of investments, at least, in education, to trigger the "mechanics of economic growth". Market forces alone can not push a country from backwardness towards catching up.

Abramovitz (1986) suggests a broad concept of "social capability" to deal with the multiple sources of economic development.[4] The multiple factors involved in the definition of "social capability"(from financial institutions to welfare conditions) are an indication a precondition for a successful catching up process: a complex process of institutional building.

Freeman (1989) and Fagerberg (1988) consider that the formation of a NSI is a precondition for a successful catching up process.

Therefore, there is a relationship between the formation of a NSI and the catching up process. This is a two-way relationship. To rephrase this relationship, it is necessary to refine the definition of the main goal for a catching up NSI. The idea of "absorptive capability" is the main point here: the process of NSI formation in backward countries must have the goal of improving the country's "absorptive capability".

Stressing the role of "absorptive capability", it is possible to specify the main difference between the technological dynamics of developed and developing countries. The main difference is that the key elements of technological change lies abroad, so developing countries must be able to absorb innovations generated in foreign countries to improve their inward condition. The idea of "absorptive capability" pinpoints two elements: 1) the main sources of technological change are foreign; 2) but it is necessary to create a basic inward capacity to the backward country assimilate such sources.

The idea of "absorptive capability" as the main goal of a backward country highlights the international links in the process of catching up. It also underlines the role of national effort to achieve such development. This two-sided process suggests a balanced position, avoiding both a "nationalist" position and a naïve faith in the promises of "international markets".

The literature about technologic innovation may provide some support to the idea of "absorptive capability" as a key goal for backward countries. Six points can be put forward.

1) Determinants of technological change. Dosi (1984, 1988) suggests that there are four main determinants: technological opportunities, appropriation conditions, cumulativity, and demand conditions. Each of these determinants have different operation conditions in backward countries. Technological opportunities are generated abroad; appropriation conditions can be a handcap for them (blocking or making more difficult the access to important technologies); the cumulative nature of technological progress can be weakened by the scarcity of firms that could support such process; demand conditions suffer from low income and its uneven distribution.[5]

2) Innovation theory. From Freeman's (1994) survey of the literature of technological change, it is possible to rank innovations in at least four categories: a) radical innovations; b) major improvements; c) incremental innovations; d) "mere" imitation and copy with negligible improvements.[6] This simple ranking of innovations provides a useful framework for the identification of key characteristics in a catching up process. Starting from a stage of "mere" copy and imitation, a backward country must upgrade its capabilities towards the stage of minor incremental innovations. This stage

involves a more creative adaptation of technologies generated abroad, allowing a broader diffusion of innovations. This evolution supposes a complex (but unavoidable) combination between technological imports with local technology accumulation (Bell & Pavitt, 1993, p. 194).

3) Firms as a central unity of analysis. At the firm level, the literature has discussed the two faces of technological activities (including those involving R&D): learning and innovation (Cohen & Levinthal, 1989). This has important implications to the idea of "absorptive capability" First, the firms are the main source of the "absorptive capability". Second, this double sided firms' process of technological activities provide an important microeconomic foundation for the understanding of "absorptive capability" at system level.

4) Focusing devices. At the firm level, Nelson (1982) discusses the importance of "knowledge to focus search". Knowledge (and investments inorder to develop it) contributes to avoid "blind search", which has a greater probability of wasting resources. Knowledge, therefore, can be seen as a useful "focusing device", contributing to avoid (or, to minimise) the waste of scarce resources of firms (and countries).

5) Evidence from economic history. Today's leading countries once were imitators and benefited from foreign technologies. Their development can not be understood without analysing the improvements in their "absorptive capabilities" (for USA, Nelson & Wright, 1992; for Japan, Odagiri & Goto, 1993; for Germany, Gerschenkron, 1962). The historical evidences show a process of upgrading in the categories of innovation performed by the developing countries, as suggested in the former topic.

6) Two paradigms for catching up based upon "absorptive capability". Japan is a major paradigm of a

successful (and long) catching up process (Ohkawa & Kohama, 1989). Sweden can be seen as a different paradigm, based in a process of technological improvement and innovation upgrading supported by "resource-rich" conditions (Edquist & Lundvall, 1993).

These six points are an initial support for the suggestion of the central role of "absorptive capability" for the catching up process. These points have implications for the process of NSI formation in backward countries. The development of "absorptive capability" means a specific interplay between firms and institutions (which constitutes an introduction to the differentiation between OECD NSIs and Catching up NSIs).Four important issues specify targets for the institutional building required for a NSI in a backward country.

1) Given the weaknesses identified at the firm level (and in the network of their interactions), the low development of their technological "division of labour", there are strong demands for: a) a complex trade-off between "selective protection" and "competitive rivalry" (Mowery & Oxley, 1995);[7] b) institutional support for the difficult transition (because it is not an automatic transition) from production capability to technological capability (Bell & Pavitt, 1993).

2) Finance to afford long term investment is crucial, given its contributions to firms' activities, and to an macroeconomic environment favourable to innovative activities. Backward countries, by definition, do not have "functional financial structures" (Studart, 1995), and the solution to this crucial issue is an important precondition for the formation of a NSI.[8]

3) Large investments in education to stimulate key aspects of "absorptive capability": a) literacy and basic education to develop capacity of "learning by doing"; b) higher education (with special attention to engineering and

science subjects), to create capacity to deliberate design and production improvements.

4) Initial investments in the scientific infrastructure. At the periphery, science is necessary for two main reasons: a) scientific infrastructure (which includes links between national and international scientific communities) can operate as a "focusing device" for technological absorption; it also provides the necessary knowledge to "focus search", as Nelson (1982) suggests (for the firm level); b) a minimum amount of scientific resources is necessary for the development of positive (and virtuous) feedback in the two-way interactions between science and technology, especially when there is an emergence of a knowledge-based economy (Foray & Lundvall, 1996).

These four points constitute the main building blocks of a NSI for catching up. Success in overcoming the issues presented by these four points means, by and large, the formation of a NSI for catching up.

These characteristics support the suggestion that NSIs for catching up may be taken as a dividing line between OECD and Non-OECD countries. Catching up NSIs constitute a "transitional" category.

Concluding this section, it is possible to present a broad division between three sets of NSIs: 1) Catching up NSIs, as a dividing line; 2) Ahead of catching up NSIs, the "mature" NSIs (the case of OECD countries); 3) Behind of catching up NSIs: "non-mature" NSIs.

Besides being a dividing line for the introduction of a rudimentary NSIs "typology", catching up NSIs are a benchmark for Non-OECD countries.

IV. Non-OECD NSIs and a rudimentary, tentative "typology"

The discussion in the previous section has suggested a simple three category typology. This section goes a step further, investigating possible divisions within the "non-mature" NSIs (the NSIs behind the dividing line of catching up NSIs).

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 suggested in section III. 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 summarise support in the literature for the initial two major divisions suggested in the latter section: 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 (1993), for example, point a characteristic that clusters India together with Latin American cases (but not with East Asian countries): weak "intra-firm technological accumulation" (p. 194). India and South Africa are countries that can be classified as "semi-industrialised" economies (as Latin American countries). They share with Latin American economies some characteristics described by Freeman (1995): the existence of a scientific infra-structure (universities, research institutes, 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).[9]

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).[10]

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.[11] Discussing high-tech industries, Porter et al (1996, p. 10) cluster the so-called "Asian curbs" together. The suggestion is to put together Malaysia, Thailand, Indonesia and Philippines in a category labelled "Asian curbs" NSIs.[12]

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:

1) "mature" NSIs (United States, Japan, and other OECD countries);

2) "catching up" NSIs (Korea, Taiwan, Singapore);

3) "non-mature" NSIs:

3.a) "Eastern and Central European Countries" (ECEC) NSIs (Russia, Hungary, Poland etc).

3.b) "old and ineffective scientific and technological structure" (OISTS) NSIs (Brazil, Mexico, India, South Africa).

3.c) "Asian curbs" NSIs (Malaysia, Thailand).

4) "others" (Pakistan, Turkey, China, Nigeria).

This rudimentary and tentative NSIs "typology" is a starting point. No more than this. It is not complete. Despite having limits, this rudimentary NSI "typology" is useful and is not incompatible with the literature surveyed.

First, it differs from the World Bank's classification. For instance, the World Bank groups countries like Brazil, Malaysia, Hungary, and Korea in the same category: upper middle income countries (World Bank, 1996). In the NSIs "typology" each of these countries is in a different category. Thus, this NSIs "typology" captures features that differentiate countries with similar income levels.

Second, this rudimentary "typology" allows the concept of NSI to be used for countries like Brazil, since it is qualified to stress the incomplete nature of the Brazilian NSI. In other words, this tentative "typology" makes the concept of NSI more workable for Non-OECD countries, such as Brazil. This "typology" is an operative and auxiliary device.

Third, being an auxiliary device, this tentative "typology" contributes to statistical evaluations and cross-country comparisons of different NSIs. These are the themes of Part II.

PART II: DATA AND STATISTICS OF NSIs' CATEGORIES

The next sections deal with a sample of 46 countries. Data availability and the inclusion of countries representing all five NSI categories were the main reasons underlying the sample choice.

The 46 countries, and their classification in the categories of the tentative typology are:

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

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

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

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

5) "Non-mature" "Asian curbs" NSIs: Indonesia, Malaysia, Philippines, Thailand;

6) Others: Turkey, China, Pakistan.

Statistical tests performed in next sections adopt this classification.

The data gathered involve information for two years (1981 and 1992), including R&D expenditures, patents granted by the USPTO, scientific papers published (according to the *Science Citation Index* – SCI –, of the *Institute for Scientific Information*), income levels.

The sources are various. The R&D expenditures are reported by the European Commission (1994). Patents granted by the USPTO are reported by the SPRU database, by the National Science Foundation (1996) and by the USPTO (through its Internet site). Domestic patents (and foreign patents granted by National Patent Offices) are reported by the WIPO. The scientific output is reported by the European Commission (1994) and by some *Scientometrics* papers. The income levels (and related general statistics) are provided by the Penn-World Table Data (Summers & Heston, 1991) and by the World Bank (1996). World Bank (1996) and UNESCO (1993) provide data about education.

The data have obvious limitations. First, the literature emphasises the weakness of patent statistics as a measure of technological activity (Griliches, 1990). Second, the literature exposes the problems in using scientific publications as a measure of scientific effort and achievement (Velho, 1987).

Furthermore, the analyses will be performed on a limited sample of 46 countries and using only two years as reference. Existing R&D statistics constraints explain this flaw. Indeed, R&D statistics are reliable almost only on OECD countries. The years selected (1981 and 1992) provide clues about the major changes in recent years, especially the rise of the Eastern Asian economies and the crisis of the Eastern and Central European transition economies.

V. 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 (Tables I and II).

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 curb" 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 curbs" 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.[13]

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.[14] 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 have a low ratio "USPTO patents/ Papers".

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

INDICATOR	USA	KOREA	BRAZIL	RUSSIA	MALAYS
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 1989-1993.

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 1989-1993; (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

4) "NON-MATURE" ASIAN CURBS 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 infra-structure, 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).

Summing up, S&T indicators permit an initial clustering of countries around the suggested NSI categories.[15]

VI. A look at the firm level: an introductory evaluation of non-OECD large firms innovative performance

The next step in the presentation of data and empirical evidence for the tentative NSI "typology" is an initial investigation at the firm level.

Patel & Pavitt (1990) investigate the technological activities of large firms. Their analysis is concentrated in 686 OECD large firms. As the objective of this paper is an examination of non-OECD countries (that compose the non-"mature" NSIs), this section analyses a set of firms left out of Patel & Pavitt paper: the non-OECD large firms.[16]

The 686 large OECD firms have at the bottom two criteria: annual sales in 1984 were about US$ 900 million, and average employment about 8,000. With these general references, the non-OECD firms were selected, according to Fortune's International 500 (*Fortune*, 1 August 1988): 47 firms have more than US$ 1,000 million annual sales, and are from countries not listed in Patel & Pavitt paper.[17]

Table III shows a general description of these 47 firms, whether they have any technological activity reported through patents granted by the USPTO, and the total of patents granted to them.[18]

TABLE III
Non-OECD large firms by country, their patenting activities, and patents granted by USPTO (1969-1994)

COUNTRY	LARGE FIRMS	FIRMS WITH PATENTS	TOTAL PATENTS
Argentina	1	0	0
Brazil	5	3	68
Chile	1	1	1
Colombia	1	0	0
India	7	2	3
Kuwait	1	0	0
Malaysia	1	0	0
Mexico	2	1	3
Saudi Arabia	1	1	1
South Africa	7	4	53
South Korea	11	8	909
Taiwan	3	3	12
Venezuela	1	0	0
Zambia	1	0	0
TOTAL	47	23	1,050

SOURCE: *Fortune*, SPRU patent database, author's elaboration.

Table III shows that, except for firms from Korea, Brazil, South Africa and Taiwan, patenting activities of the non-OECD large firms are negligible. This is not an unexpected result, and it confirms a point put forward in the last section: the weakness of firms' innovative activities is a major handcap of "non-mature" NSIs. As shown, 24 firms had no patent granted by USPTO.

Only 6 firms had more than 20 patents granted in the whole period: 4 from Korea (Samsumg, Lucky-Goldstar, Daewoo and Hyundai); 1 from South Africa (AE+CI); and 1 from Brazil (Petrobras).

Five important points follow from these data.

First, by these criteria the borders within "non-mature" are not clear-cut: Argentina's large firm (YPF, a petroleum refining company) had no patents, like Malaysia's firm. Even a differentiation with a possible "non-existent" NSI, like the case of Zambia, is blurred: Argentina, Malaysia and Zambia have large firms with no USPTO patent.

Second, Taiwan's large firms do not have a good performance by this criterion. At first glance, this evidence contrasts with Taiwanese catching up process, which is demonstrated by the increase in their USPTO patent numbers (zero in 1969; 79 in 1981 and 1,000 in 1992). Chong (1995) solves this puzzle: small firms and individuals are responsible for a major share of Taiwanese patents. The literature reports the role of small firms in the Taiwanese growth (Wade, 1990).

Third, Korea is a "well-behaved" case, as its catching up process is clearly shown by these data. Of course, as the Korean catching up process is strongly supported by its "chaebols" performance, large firms' patent data display the main features of such process.

Fourth, Brazilian and South African large firms have a pattern that fits with their "non-mature" OISTS NSI characteristic: there is a certain level of patenting activities.

Fifth, the Indian case suggests that for "non-mature" NSIs further investigations should be done using data from their national patent offices. As Rajeswari (1996) reports, Indian public firms do not perform well in a ranking of organisations sorted by their patenting activities. They are at a modest fourth position. However, all Indian large firms in 1988's Fortune list are "stated-owned". Therefore, a closer look at their national data might present valuable information. This conjecture is supported by the Brazilian data (Albuquerque, 1997). For example, although the data from Brazil's national patent office (*Instituto Nacional de Propriedade Industrial*, INPI) show the steel industry at a second place in the ranking of leading firms in patenting activities, they are almost absent at the USPTO list.

In sum, the data analysed in this section show a very weak performance of large non-OECD large firms (except

Korea, a catching up NSI). Although these data are useful to distinguish "mature" from "non-mature" NSI, they do not provide clear borders within the latter.

VII. "Opportunity taking indicator": investigating the usefulness of non-OECD scientific infra-structure

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. Section III suggested one role: a "focusing device" for the catching up process. Now, it is necessary to investigate if there is support for this suggestion.

There is an extensive literature discussing the complex and multifarious interplay between science and technology (Rosenberg, 1976; Pavitt, 1991; Klevorick et al, 1995; 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 infra-structure 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 infra-structure. As a "focusing device", this scientific infra-structure 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 publications statistics.[19] 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 (section II). 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.

To evaluate a possible meaning of OTI, a starting point is a situation where, hypothetically, the two shares are similar. For example, a country has 10% of world's scientific papers and 10% of USPTO patents. Its OTI is one. It seems to be a balanced situation, with a balanced interaction between the two dimensions of its NSI. Theoretically, its scientific infra-structure is a good source of technological opportunities, trained researchers etc. And its productive sector feeds the scientific community with problems, demands, and resources.

One different example could be a country that has not such balanced shares. Now, the imaginary country has 30% of world's scientific papers, but only 5% of USPTO patents. Its OTI is 0.16. It hints a more unbalanced situation than the former example. Probably, the scientific institutions are producing knowledge that has not been useful to its industries. Or, its industries are not able to take advantage of available national resources. Or, a two-way problem. Summing up, there might be problems in the interactions and in the interconnectedness of the system.

Alternatively, the opposite of the latter example could be supposed. A country that has 5% of world's papers, but 30% of USPTO patents. Its OTI is 6.0. Probably, its scientific infra-structure is providing not only a useful guidance for industrial development (and providing resources for industry), but also contributing to link the country to international scientific and technological flows.

This very simple (and hypothetical) examples help to develop the intuition with OTI. 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 IV presents OTI results, calculated from data for the 46 countries sample. OTI values are presented for the years of 1981 and 1992.

TABLE IV
"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 Curbs	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 Curbs	4	0.187	0.206	1.102

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

Table IV 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 have 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 IV. This points 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 curbs" 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);[20] 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).

Summing up, 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.

VIII. 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.

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. Summing up, 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 have 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 spill-over to civilian uses). The weak interactions 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 curbs" 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.

The case of this category highlights a point that deserves further research: there are certain levels of economic growth, probably behind certain threshold value, that are not reflected in USPTO patent data. The recent trajectories of the "Asian curbs" have precedents in economic history. Indonesia, Thailand and Malaysia had good growth performances in the last decade. Table II displays comparative levels of GPD per capita (taking USA as a benchmark).

TABLE V
Comparative levels of GDP per capita (USA = 100),selected "non-existent" NSIs (1981-1992)

COUNTRY	1981	1992
Indonesia	9.6	11.2
Malaysia	25.5	31.0
Philippines	11.9	9.4
Thailand	14.2	21.6

SORCE: Penn World Table (Summers & Heston, 1991).

Except for Philippines, Table II shows a growth performance. However, this performance had no impact in their USPTO patenting activities. This observation points to a problem with the utilisation of patent data as catching up indicators. Patents do not capture all reductions in the gap with developed countries. This is a problem identified in other catching up phases. Historically, Brazil, Korea and Taiwan are other examples of this "identification problem".[21] Of course, there are lags in this relationship. But, a conjecture could be investigated. USPTO patent data is not correlated with income changes until a certain threshold level of development is overcome.

Summing up, the main characteristics of "Asian curbs" NSIs might not be 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.[22]

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.[23]

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 curbs NSIs, and

D3 = 0, otherwise.

D4 = 1, if "others";

D4 = 0, otherwise.

Table VII reports the results.

TABLE VII
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 Errorof 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.

To examine whether or not the R-sq. found in Table VI 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.[24]

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.[25]

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.

IX. Domestic patents: information and conjecture

This section presents data about domestic patents (patents granted by National Patent Offices). This section organises these data, investigating whether domestic patents highlight NSIs characteristics.

Domestic patents have a division between patents granted to Residents and to Non-residents.

WIPO (and National Patent Offices) defines as residents every individual, institution, and firm that work in a given country.

The category of residents can be divided according to the ownership structure, as follows: a) individuals; b) domestic private capital; c) foreign capital; d) state-owned national firms; e) research institute or university; f) government agency. These criteria define a multinational subsidiary as resident of the host country.

An introductory observation links this section with the latter: there is a significant correlation between domestic patents and USPTO patents. Table VIII shows the correlation between data for the 46 countries sample.

TABLE VIII
Correlation between the patent data from USPTO and from National Patent Offices (for Residents and Non-residents patents' owners), 46 countries sample (1981 and 1992)

	1981	1992
USPTO x Residents Patents	0.803	0.819
USPTO x Non-resident Patents	0.640	0.614

SOURCE: USPTO and WIPO, author's elaboration.

This correlation is important, because it stresses the comparability between the two types of patents. But, domestic patents have economic meaning different from USPTO patents: a) domestic patents provides a better picture

of innovative activities of one country than USPTO figures, as the former involves patents with lower technological content (local improvements, adaptations of foreign technologies); b) domestic patents have national markets as a target, while USPTO patents target international markets.

The break down of domestic patents between Residents and Non-residents points another differentiation.

On the one hand, patents granted to residents are an expression of the output of internal technological activities. It may be a "proxy" of the country technological condition.

On the other hand, patents granted to non-residents represent the importance of the national market to foreign corporations, institutions and individuals. They apply for patents to secure market shares in target countries (Penrose, 1974). Among other factors, the openness of a national market influences these data.

Thus, a major difference between the two categories is whether they represent an output of internal innovation activities or display the importance (and openness) of national markets to foreign patent owners.

These observations introduce a ratio (shown in Table IX): patents granted to residents divided by patents granted to non-residents. Ostry & Nelson (1995) suggest that this ratio inform the level of foreign technological diffusion in an economy. This ratio, however, conveys various information simultaneously: a) high level of resident patenting shows technological strength, but it may also mean that national patent laws have played a significant role in determining how many patents derive from an innovation; b) high level of non-residents patenting displays openness and diffusion of new foreign technologies, but it may also only mean that a national market is worthwhile for foreign corporations in the future, so they patent to secure market positions. The ratios shown in Table IX might express different mix of these, sometimes contradictory, information. Therefore, it is not clear that this ratio expresses levels of technological diffusion. A closer analysis is necessary to evaluate each case.

TABLE IX
Ratio Residents/Non-residents patent owners, average values for the 46 countries sample, and according to NSIs categories
(1981 and 1992)

	1981	1992
All countries	0.541 (34)	0.998 (41)
Mature NSIs	0.549 (19)	0.505 (20)
Catching up NSIs	-	0.515 (1)
OISTS NSIs	0.257 (10)	0.118 (9)
ECEC NSIs	1.734 (3)	4.756 (6)
Asian curbs NSIs	0.096 (1)	0.034 (2)
Others	0.102 (1)	0.217 (3)

SOURCE: WIPO, author's elaboration.

Three observations can be drawn from Table IX.

First, the ranking between "mature", OISTS and Asian curbs could be explained by a declining domestic technological strength (mature NSIs high, Asian curbs low). The Asian curbs case probably shows the high level of foreign patenting in countries where national capabilities begin to develop. Probably, in this case this ratio hints a high level of foreign technology diffusion.

Second, the average value for the ECEC NSIs could be explained by a combination of two factors: a) the closed character of those economies blocking foreign patenting; b) the existence of a relevant level of internal technological activities.

However, the high 1992 ratio for the ECEC countries is puzzling. It seems to be responsible for the abnormal increase in the "all countries'" average. The radical current changes in those countries might provide an explanation. But, if the numbers of patent applications are analysed, instead of those of patent granted, the average ratio declines

to 0.504 in 1992. This average probably anticipates a future change in the ratio for patents granted.[26]

Third, looking at the country level (outside the ECEC set), only United States and Japan had in the three years analysed a ratio greater than one. Germany had ratios almost equal to one in 1977 and 1981, and a ratio greater than 0.600 in 1992. These are significant results, expressing technological strengths that are identifiable.

Catching up processes are not well captured by the latter ratio. The ratio may keep unchanged, while both residents patents grow (technological strength) and foreign patenting rises (growth of internal markets, income levels).

Table X reports data from Korea and Brazil (1975-1992). Inter-temporal changes in absolute levels of patenting activities seem to be a good indicator of catching up process. Table X illustrates clearly the different technological trajectories of Brazil and Korea. Brazilian stagnation contrasts with Korean catching up. Both trajectories are captured by domestic patenting and USPTO data.

TABLE X
Patents Granted to Residents by National Patent Offices (NPOs) of Korea and Brazil, and patents granted to Inventors from Korea and Brazil by the USPTO (1975-1992)

YEAR	KOREA		BRAZIL	
	N.P.O.	USPTO	N.P.O.	USPTO
1992	3.570	538	254	40
1991	2.553	402	341	61
1990	2.554	225	453	41
1989	1.181	159	474	36
1988	575	97	487	29
1987	596	84	289	34
1986	458	45	442	27
1985	349	38	607	30
1984	297	29	582	20
1983	245	26	776	19
1982	274	14	1.308	27
1981	232	15	844	23
1980	186	8	349	24
1979	258	4	175	19
1978	133	12	-	24
1977	104	5	140	21
1976	191	7	180	18
1975	212	11	82	17
TOTAL	13968	1719	7783	510
AVERAGE	776	95.5	457.8	28.3
ST-DEV.	995.7	146.3	297.8	10.7
COEF.VAR.	1.3	1.5	0.7	0.4
CORREL. USPTO x NPO:	0.97		-0.03	

SOURCE: USPTO; WIPO.

One interesting point shown by Table X is the inter-temporal correlation between the two national sets of data. It is significant and high in the Korean case (0.97), but not significant, and even negative in the Brazilian case (-0.03).

The Korean pattern displays a clear catching up process. The growth of technological capability reported by NPO figures is followed by a corresponding change in USPTO data.

Although the coefficient of variability in the Korean case is greater, the correlation index is high. Instead, in the

Brazilian case the coefficient of variability is smaller, but the correlation index is very low. This suggests that Brazil "wandered" around the same technological level, without a clear (growing) path.

Finally, Table XI shows the ratios between USPTO and domestic patents granted to residents by National Patent Offices. The intuition behind this relationship is simple: national residents patents constitute a "stock" of innovations, from where the more sophisticated, and the more worthwhile are selected to be applied to the USPTO.

TABLE XI
Ratio USPTO/Residents patent owners,average values for the 46 countries sample,and according to NSIs categories
(1981 and 1992)

	1981	1992
All countries	0.349 (34)	0.437 (41)
Mature NSIs	0.566 (19)	0.702 (20)
Catching up NSIs	-	0.151 (1)
OISTS NSIs	0.138 (10)	0.156 (9)
ECEC NSIs	0.048 (3)	0.027 (6)
Asian curbs NSIs	0.130 (1)	0.882 (2)
Others	0.077 (1)	0.071 (3)

SOURCE: WIPO, author's elaboration

First, the ranking of "mature" and "non-mature" NSIs can be explained by the expected higher quality of national patents of technological leaders countries or successful catching up nations. Thus, the quality of "immature" countries' patents is lower than the "mature" NSIs. This means that domestic patents of residents in "non-mature" NSIs represents imitative activities, adaptations and minor improvements (probably, adjusting foreign innovations to national characteristics of production and consumption).

Second, the smaller ratios for ECEC NSIs may be explained by their low integration within world economy in general, and with United States markets in particular.

Third, the "Asian curbs" NSIs perform an unexpected pattern (as they were supposed to rank behind "non-mature" OISTS NSIs). The low level of national patenting activity probably disturbs this relationship.[27]

Concluding this section, a general balance of the contributions of domestic patenting data to the evaluation of NSI must be weighted carefully. Domestic patents provide useful information, but need close examination. Changes in absolute levels of patenting activities (correlated with changes in USPTO figures), however, seem to be a good indicator of successful catching up process.

X. 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".

Again, measurement problems are present. They grow when Non-OECD countries are evaluated (Velho, 1987).

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 VIII, 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 infra-structure; 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 infra-structure. And, as discussed in section VII, the functioning of their scientific infra-structure 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 infra-structure, 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 feedbacks effects (from industry to science), and diminishes the scientific output. Budgetary constrains threaten the stability of research groups, and, again, affect the output. There 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 infra-structure and world level science. There were huge investments in the scientific sector in these countries. Although the feedbacks 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 curbs NSIs have the smallest scientific infra-structure 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 VIII 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 curbs NSIs, and

D3 = 0, otherwise.

D4 = 1, if "others";

D4 = 0, otherwise.

Table XI reports the results.

TABLE XII
Log R&D X Log Scientific 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.

To examine whether or not the R-sq. found in Table XI 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.[28]

The hypothesis is not refuted for 1981 data. In this year, "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 curbs" ranked behind them.

However, for 1992 the results were 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 curbs" 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).

XI. 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.

Taking catching up NSIs as a benchmark, the tentative "typology" is put forward.

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 by the few data analysed in Part II. 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.

Notes

[1] This suggestion was present on an earlier paper (Patel & Pavitt, 1994).

[2] As will be shown in section IV, some OECD members can not be considered as "mature" NSIs: Spain, Portugal, Turkey, and Greece. These exceptions must be kept in mind. For simplicity, the remainder of the text will use the term OECD countries to describe the set of "mature" NSIs.

[3] As already putted forward, Patel & Pavitt (1994) divide OECD countries between "myopic" and "dynamic". Other divisions could be made, for instance, differentiating resource-based NSIs from the rest (European Commission, 1994).

[4] Abramovitz (1986) mentions that the concept of "social capability" was first suggested in an evaluation of the Japanese development. Ohkawa & Kohama (1989) discuss the "lessons from Japan", emphasising the importance of improvements in "social capability" to the whole process of this century.

[5] Albuquerque (1996b) presents arguments for these different conditions. In this text, the argument is built upon the identification of differences between the uncertainty prevailing in developed and backward countries.

[6] These categories are not incompatible with an important point stressed by the theory of innovation: it is not correct to consider a "diffusion" a passive process, almost opposed to the active "innovation" process. "Diffusion" is not possible with effort, learning, and adaptation. Therefore it depends upon a certain kind of continuity of innovation (Silverberg, et al., 1988).

[7] This trade-off may take as reference the observations of Ostry & Nelson (1994).

[8] OECD countries have different financial structures (Zysman, 1983). But, using Studart's (1995) suggestion, it is sufficient to state that the main difference between the OECD and Non-OECD countries is the existence (or not) of a functional financial system. For an introductory articulation between NSIs and financial structures, see Albuquerque (1996b). For a recent survey of the problem involving banking activities in Non-OECD countries, see *The Economist* (Survey: Banking in Emerging Markets, 12 April 1997).

[9] Economic history is important to cluster these countries together. Latin American countries, India and South Africa had industrial policies shaped by "import substitution models", for instance.

[10] Bell & Pavitt (1993) cite China as a country that shares a characteristic with India and Latin American countries: the already mentioned weak intra-firm technological accumulation.

[11] *The Economist* (March 1st, 1997, p. 24) reports for Malaysia and Thailand a TFP annual growth greater than 2%, between 1978 and 1996.

[12] Again, economic history is important here. These countries have been deeply influenced by the Japanese growth and by the recent success of "Asian tigers". There are important regional factors as well as the use of their successful neighbours as models for economic and technological policies.

[13] Section VII discusses one possible meaning of this "ratio".

[14] Ostry & Nelson (1995) suggest this interpretation of the ratio "domestic/foreign patents". The ratio for "mature" NSIs is high because of Japanese figures. As will be discussed later (Section IX), it is not so straightforward to identify the ratio "domestic/ foreign patents" as a measure of technological diffusion. At least, for the Japanese case, it is disputable.

[15] As mentioned earlier (section IV), probably there might be a "non-existent" NSI category. Countries like Zambia and Pakistan are candidates to this classification. But, even there some differences do exist. In 1992 Pakistan allocated 0.96% of its GNP to R&D, but had only one USPTO patent (and only 11 domestic patents granted. Pakistan had an illiteracy level of 62%. Although it had a relatively high level of R&D expenditure, Pakistan seemed to have no significant technological activities. Probably, the share of military R&D is very high, explaining the huge ineffectiveness of these expenditures. This case is different in other countries that have negligible R&D expenditures (Zambia, Nigeria, for example). However, these two cases seem to be examples of "non-existent" NSIs. Further discussions should investigate this important set of countries.

[16] Although here classified as an "immature" NSI, Spain (an OECD country) is included in the 686 firms sample (there is one Spanish firm, which principal activity is "motor vehicles"). Like Portugal, Greece and Turkey, they are not included in the firms set analysed in this section. Indeed, this section concentrates its analyses in "non-OECD", "non-mature" NSIs, and capitalist countries (in 1988).

[17] The criteria of this selection are less rigorous than Patel & Pavitt's paper. For example: while Spain has 8 firms in Fortune's list, only one Spanish firm was included in the 686 large firms set.

[18] According to Fortune's industrial classification, these firms' sectors: a) petroleum refining, 15; b) mining, crude-oil production, 8; c) chemicals, 6; d) electronics, 6; e) metals, 5; f) textiles, 2; g) motor vehicles and parts, 2; h) food, 1; i) transportation equipment, 1; j) beverages, 1.

[19] Sections VIII and X indicate some criticisms of patents and papers as S&T indicators.

[20] 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 1989-1993, in disciplines like "Materials Science" its share was 0.97 (Braun et al, 1995).

21 Without significant changes in USPTO patent levels, Brazil, Korea and Taiwan performed important reductions in the income gap. Their gaps with USA income level were reduced as follows: a) Brazil: 51,35% between 1970 and 1980; 2) Korea: 127,59 % between 1960 and 1980; c) Taiwan: 64,42% between 1960 and 1973.

22 The literature surveys cross-section relationship at the firm and/ or industrial sectors levels (Griliches, 1990; Bound et al, 1984).

23 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".

24 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.

25 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.

26 The statistics of patent applications display a more dynamic picture of economic process, because their time-lag are shorter than the patent grants case.

27 The "Asian curbs" figures for 1992 are biased by Malaysian data: this country granted more patents in the USPTO than in its National Office.

28 The regression normalised by population size found variables "dummy" for intercept (instead of slope, as in Table VII). 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 VII.

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