RELAZIONE SCIENTIFICA

ELABORAZIONE DI UN APPROCCIO SISTEMICO PER UNA ANALISI ECONOMICA COMPARATA DEL SISTEMA INNOVATIVO ITALIANO

by **MARIO COCCIA**

National Research Council of Italy

The crisis of international markets and growing financial globalisation and integration, has raised an interest in the economic analysis of the relationship between innovation and economic performance of countries. In fact, nowadays is more and more necessary to measure and evaluate the economic and technological performance of country to decide suitable economic and research policy that support the economic growth of nations.

Mario Coccia from Italian National Research Council has studied at University of Maryland (USA) a systemic approach to analyze the national system of innovation of Italy in comparison with other economies. The research proposes a new taxonomy for performance identification of country based on principal component analysis. The paper investigates 51 countries and a set of 13 indicators of economic and technological performances for the period 2000-2002. The methodology reduces the variables and groups the countries that show similar strategic behaviour in the global marked. The taxonomy facilitates the identification of country performance and provides relevant information to policy-makers concerning the strength and weakness, opportunity and threat of Italy in comparison with other countries. The Italian policy-makers can use this research to support *best-policy practices* to increase the wealth of the nation**.** Moreover, to complete this research we are going to analyze, next year in collaboration with University of Maryland and George Washington University, the data set of World Bank to improve the findings.

ATTACH: DRAFT OF THE RESEARCH ACTIVITY AT UNIVERSITY OF MARYLAND (USA)

Proponente Dirigente di ricerca del CNR — Fruitore

Secondo Rolfo — Mario Coccia

Bozza articolo

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ECONOMIC AND TECHNOLOGICAL ANALYSIS OF COUNTRY PERFORMANCE AND COMPARISON OF ITALIAN NATIONAL SYSTME OF INNOVATION IN A GLOBAL CONTEXT

I. Introduction

The crisis of international markets following recent events, such as terrorist attacks, wars in the East, and growing financial globalisation and integration, has raised an interest in the comparative analysis of countries. Facing such a turbulent scenario of the markets, uncertain for nations and international investors alike, it is essential to measure and evaluate the country performance and risk (Nath, 2004; Cruces *et al.*, 2002; Merton, 1974; Ortiz and Rodríguez, 2002). Country assessment is important because it also provides information on economic instability, probability of default (Balkan, 1992) and so on. Country evaluation is difficult due to several factors, such as the lack of a liquid market, which makes it difficult to attribute a price to a country. Therefore, country assessment has very often been based on different approaches, such as balanced score cards, ratings, structural models, interest yield, etc. (Bouchet *et al.*, 2003).

A wide range of techniques commonly used in countrymetrics are based on multivariate statistics such as the Discriminant Analysis and the Principal Component Analysis (PCA in short, see Scherer and Avellaneda, 2000). The purpose of this paper is to propose a taxonomy, which show the strategic behaviour of countries in a global context. The methodology uses the PCA to integrate the approaches based on multivariate analyses. This research fills a gap in the economic literature about country risk assessment because it extends the methodologies that use the PCA technique and it provides a simple classification scheme, which facilitates the identification both of economic and technological performances of countries, and of country risks. The results of the analysis can provide information both to international investors and to policy-makers, who must decide about suitable investments in foreign countries and economic policies in order to increase the economic growth and wealth of the nation.

Section II of this research introduces the theoretical framework. The methodology of the analysis, which is based on multivariate technique, is described in section III. Section IV displays the results and findings of the research, using a data set of 51 countries and 13 leading economic and technological indicators for the period 2000-2002, while section V deals with concluding remarks.

II. Theory (to be completed)

Country risk assessment is based on three methodological approaches (Bouchet *et al.*, 2003): *a) qualitative approach to country risks;* it refers to the assessment of the economic, financial and socio-political fundamentals that can affect the investment return prospects in a foreign country. Instead of focusing on a range of ratios or indices that are supposed to reduce a complex situation into one single figure, the qualitative analysis aims at tackling the structures of a country's development process to shed light on the underlying strengths and weaknesses; *b) the ratings or rank-ordering comparative approach* aims at providing an overall view of relative risk when facing foreign investment decisions. There are as many rating methodologies as there are rating entities, depending on different types of investment and the various sources of risk; *c) econometric and mathematical methods*, which may be synthesised as follows:

- Discriminant analysis (Altman, 1968)
- Principal component analysis (Scherer and Avellaneda, 2000)

- Non-linearities and non-parametric estimation (Kaminski and Reinhart, 1999)
- Logit and probit models
- Regression analysis (Pagès, 2001)
- Monte Carlo simulations
- Value at risk (Pritsker, 1997)
- Artificial neural networks
- Multicriteria decision making

Further methodologies include: the international analysis of portfolio investments (Eaton and Gersovitz, 1987), the measure of political risk as an insurance premium (Clark, 1997), and other approaches such as those of Kobrin (1996), Feils and Şabac (2000), Chan and Wei (1996), Cutler *et al.* (1989), Bittlingmayer (1998), and so forth. Oetzel *et al*. (2001) examine eleven widely used measures of country risk across seventeen countries during a nineteen-year time period. The results raise important questions about the usefulness of these measures and why managers still choose to use them.

As this research applies econometric methods, the present section focuses on these methodologies to clarify some of their most relevant aspects, which are used in the following paragraphs of the paper. The principal component analysis (PCA) is a mathematical method to determine the linear transformation of a sample of points in an *N*-dimensional space, which most clearly shows the properties of the sample along the co-ordinate axes. Along the new axes the sample variances are extremes (maxima and minima), and uncorrelated. PCA uses the historical variance/covariance of a data set to extract a set of indices that best explain the variance of the data (Fabbris, 1997). The name PCA comes from the *principal axes* of an ellipsoid. PCA extracts components to maximise the proportion of variability explained by each component, subject to the orthogonality constraint. It proceeds sequentially. The first index generated by the methodology best explains the variance of the original data and is called the first component principal. After the first index is selected, the analysis proceeds to extract the index that explains as much as possible of the variance of the original data that is unexplained by the first principal component, given that this second index is constrained to be uncorrelated (orthogonal) with the first index. This index is called the second principal component. The process continues until the number of indices equals the number of variables in the data set (Bouchet *et al.,* 2003). The objectives of PCA are: a) to discover or to reduce the dimensionality of the data set; b) to identify new meaningful underlying variables. As the axes are rotated, the variable loadings change. One criterion to find the 'simplest' combination of loadings is the Varimax method, which uses the variance of the loadings to achieve a solution in which each loading is as close as possible to either 0 or 1. Factor loadings are correlation coefficients, thus if a variable has a large (absolute) loading it is highly correlated with a factor, while a small loading indicates no correlation. The aim of the Varimax rotation is to remove, as far as possible, loadings in the mid range (e.g.: 0.3 - 0.7). Ideally, each variable will have a large loading for only one factor.

In a recent paper, Scherer and Avellaneda (2000) use the principal component analysis to study the Broady bond debt of Argentina, Brazil, Mexico, and Venezuela. They find that there are two statistically significant components or factors that explain up to 90% of the realised variance. The component that explains the most variance corresponds to variance attributable to regional (Latin) risk. The second component suggests the existence of a volatility risk factor associated with Venezuelan debt in relation to the rest of the region. A time-dependent factor analysis shows that the importance of the variance explained by the factors changes over time and that this variation can be interpreted in terms of market events, such as the Mexican peso crisis, the Asian economic meltdown, the Russian default and the devaluation of the Brazilian real (Bouchet *et al.,* 2003). Although there are several researches on country assessment, which apply econometric methods, the economic literature lacks a simple taxonomy based on multivariate approaches. The purpose of this paper is to apply the PCA to measure and evaluate the economic and technological performances of countries, in order to propose a new taxonomy. This taxonomy provides information to policy-makers about the strategic behaviour of countries within the global scenario in order to support economic policies necessary to increase the economic growth of countries and/or geo-politic areas. Such a new taxonomy of countries is substantially easier and quicker to analyse than the approaches that use conventional methodologies.

III. Methodology (work in progress)

Taxonomies are meant to classify phenomena with the aim of maximizing the differences among groups. The term *taxonomy* refers to the theory and practice of producing classification schemes. Thus, constructing a classification is a taxonomic process with rules on how to form and represent groups (Greek word: *taxa*), which are then named (Greek word: *nomy*). Taxonomies are useful, if they are able to reduce the complexity of the population studied into easily recallable macro-classes. Classification as an output (a product of the process of classifying) deals with how groups and classes of entities are arranged, according to the taxonomic approach used. This theoretical framework orders and represents complex phenomena in a simple manner through a matrix, a table, a map, etc.

The methodology used in this research to propose a taxonomy of country performance and risk, using economic and technological indicators, is based on the application of the multivariate analysis (Fabbris, 1997). In particular, it draws on the analysis of principal components, in order to orthogonalize the variables and reduce them, and to group the countries into categories based on high/low economic and technological performances. The sources of data are *The Economist Intelligence Unit* (EIU, 2005) and *OECD Statistics* (2004). The sample, made up of 51 countries, is divided as follows: 2 countries in North America, 8 in South America, 15 in Europe, 8 in Eastern Europe, 1 in Africa, 15 in Asia, and 2 in Oceania. A set of 13 indicators for the period 2000-2002 measures the economic and technological performances of each country. These indices represent the leading indicators of the economic and innovation system of countries. In fact, the following ten economic indicators are used, because they provide information on the wealth of the nations, as well as on economic stability, labour market, and international economics:

1. Gross Domestic Product (GDP) per head (U$ Dollar at PPP[1]) of *i-th* country
2. GDP (% real change pa) of *i-th* country
3. Government consumption (% of GDP) of *i-th* country
4. Budget balance (% of GDP) of *i-th* country

[1] Purchasing Power Parity (PPP) is a theory, which states that exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries. This means that the exchange rate between two countries should equal the ratio of the two countries' price level of a fixed basket of goods and services. When a country's domestic price level is increasing (a country experiences inflation), that country's exchange rate must be depreciated in order to return to PPP. The basis for PPP is the "law of one price."

5. Consumer prices (% change pa; av) of *i-th* country

6. Public debt (% of GDP) of *i-th* country

7. Labour costs per hour[2] (USD) of *i-th* country

8. Recorded unemployment (%) of *i-th* country

9. Foreign-exchange reserves (mUS$) of *i-th* country

10. Current-account balance/GDP of *i-th* country

$\forall i \in \{1, 2, \ldots, 51\}$

On the other hand, the three technological indicators, used in this analysis, are the basic indicators applied to all the analyses on the national systems of innovation (Lundvall, 1992). In fact, they provide relevant information on the capability of countries to produce scientific research and innovations (Sharif, 1986), which increase the productivity of firms and the economic growth of the nations (Lucas, 1988; Romer, 1990; Aghion and Howitt, 1992). They are given by:

11. Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP)
12. GERD per capita population (U$ Dollar at PPP)
13. Total researchers per thousand labour force

The data analysed refer to the arithmetical mean of these indicators for the 2000-2001-2002 period. The indicators are then standardised in order to make it easier to compare them. The economic indicators are the variables of the principal component analysis, which uses the Varimax method and Kaiser normalisation, in order to orthogonalize the variables and reduce them. The PCA identifies three principal

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[2] For production workers. Includes pay for time worked, other direct pay (e.g. holiday pay), employer expenditures on legally required insurance programmes, and other labour taxes.

components that embody all the characteristics of the aforementioned ten economic indicators.

The names of the categories constructed are based on the following hypotheses:

H1. Countries with a LOW rate of consumer price (%), of recorded unemployment (%), of Budget balance % of GDP (low if the value is negative, high if positive), and a HIGH value of Foreign-exchange reserves (mUS$), *have a stronger economic stability than* countries with a HIGH rate of consumer price (%), of recorded unemployment (%), of Budget balance % of GDP (high if the value is negative, low if it is positive), and a LOW value of Foreign-exchange reserves (mUS$).

H2. Countries with a HIGH rate of GDP (% real change pa), of Current-account balance/GDP, Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP), of GERD per capita population (U$ Dollar at PPP), of total researchers per thousand labour force, and a LOW rate of recorded unemployment *have a stronger economic growth than* countries with a LOW rate of GDP (% real change pa), of Current-account balance/GDP, of GERD as a percentage of GDP, of GERD per capita population (U$ Dollar at PPP), of total researchers per thousand labour force, and a HIGH rate of recorded unemployment.

H3. Countries with LOW performances measured by economic and technological indicators have a HIGH country risk.

The complexity and abundance of calculations, due to the high number of cases and variables, are overcome by the application of the SPSS® statistical package, which provides all the results described and analysed in section IV.

IV. First Results and findings

The analysis of the principal components (PCA), using the economic indicators, produces three new variables (principal components or factors). In fact, from the initial matrix of 51 (countries) × 10 (indicators), a new matrix is created: 51 (countries) ×3 (principal components or factors).

Table 1 displays the closeness in correlation (*rotated loadings*) between each of the three components and each economic indicator. It can be clearly seen that the indicators labour costs per hour, GDP per head, and budget balance *contribute most to with component 1* (Labour costs per hour = 0.90; GDP per head = 0.88; budget balance = 0.66); on the contrary, the variables current-account balance /GDP with 0.68, and foreign-exchange reserves with 0.67 *contribute most to component 2*; last, the indicator public debt with 0.78 *contributes most to component 3*.

Table 1. Rotated Component Matrix

Standardized Variable	**Component**		
	1	**2**	**3**
Labour costs per hour (USD)	0.90	0.26	0.17
Current-account balance/GDP	0.12	0.68	-0.13
GDP (% real change pa)	-0.35	0.22	-0.61
Public debt (% of GDP)	0.06	0.03	0.78
Budget balance (% of GDP)	0.66	0.22	-0.54
Recorded unemployment (%)	-0.26	-0.70	0.19
Consumer prices (% change pa; av)	-0.46	-0.37	0.01
GDP per head ($ at PPP)	0.88	0.30	0.09
Foreign-exchange reserves (mUS$)	-0.11	0.67	0.46
Government consumption (% of GDP)	0.78	-0.27	0.18

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Rotation converged in 10 iterations.

Table 2 displays the validity of this PCA, i.e. of the compression from matrix 51×10 to matrix 51×3. It shows the total variance explained of the new matrix 51×3:

one principal component has a percentage of cumulative variance of 33.98 (third column); two principal components of 51.32; three principal components of 65.17. This analysis is based on three principals components, since the *first component* explains as much as possible the historical variance/covariance matrix, the *second and third* explain as much as possible of the remaining variance, while the last few principal components have relatively little explanatory power. In fact, most of the correlation matrix, in this research, is explained by the first three principal components.

Table 2. Total Variance Explained

	Initial Eigenvalues		
Component	**Total**	**% of Variance**	**Cumulative**
1	**3.40**	**33.98**	**33.98**
2	**1.73**	**17.34**	**51.32**
3	**1.39**	**13.85**	**65.17**
4	0.95	9.49	74.66
5	0.75	7.52	82.19
6	0.63	6.32	88.50
7	0.53	5.25	93.75
8	0.36	3.59	97.35
9	0.19	1.90	99.24
10	0.08	0.76	100.00

Extraction Method: Principal Component Analysis.

If the first two principal components (or factors) are represented geometrically, it is possible to analyse the strategic position of countries within the following map (figure 1).

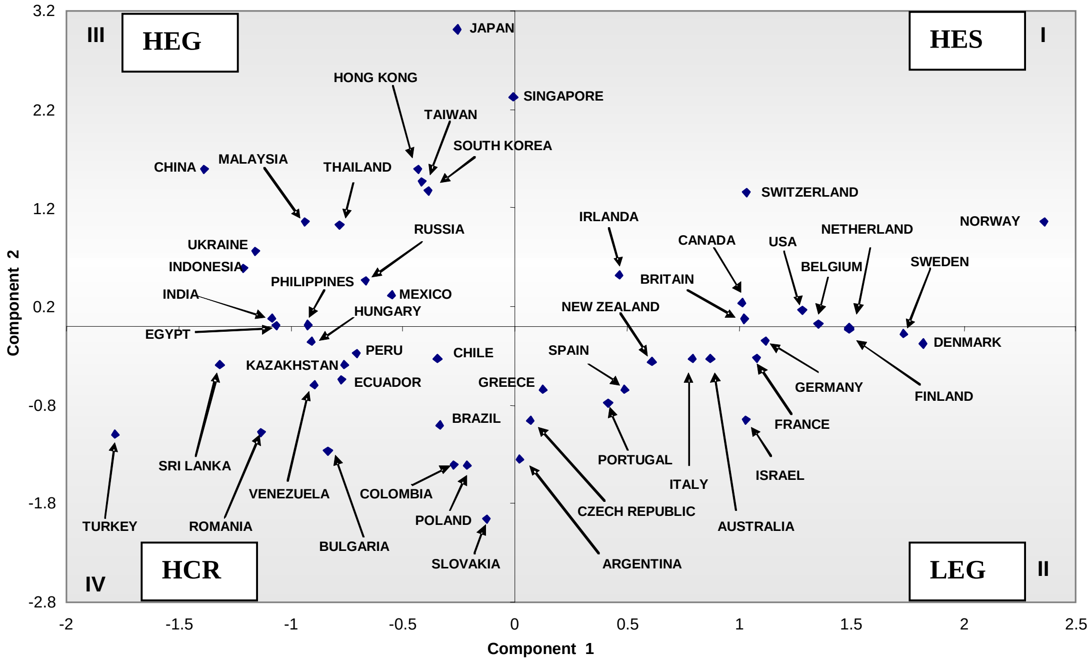

Figure 1. Map of the strategic location of countries according to their economic performance

The results of the principal component analysis using economic indicators, makes it possible to pinpoint some sets that allow for a homogeneous grouping of countries which have similar characteristics and behaviour. The new taxonomy of countries is constructed by means of the following steps: a) the map in figure 1 shows 4 quadrants (from I to IV), where countries with different economic performance are located; b) the economic and technological performances of these 4 sets are synthesised through the arithmetic mean of the indicators, for the period 2000-2002 (see Table 3).

Using the above-mentioned hypotheses (H1, H2, H3), the result of this taxonomic process is the following classification of country performance and risk:

- *HES*: High Economic Stability (I quadrant or north east corner)
- *LEG*: Low Economic Growth (II quadrant or south east corner)
- *HEG*: High Economic Growth (III quadrant or north west corner)
- *HCR*: High Country Risk (IV quadrant or south west corner)

The main characteristics of these four types are now described in detail, trying to point out their structural elements.

- *HES: High Economic Stability* are countries characterised by the fact that the figures referring to the main economic indicators (Government consumption, budget balance, inflation, public debt, labour cost, unemployment, foreign-exchange reserve) have a bounded range. This ensures the nation's economic-financial stability: these values comply with the indications of the Maastricht Treatise used by European Union countries to maintain economic stability within the Eurozone. Furthermore, the growth of the GDP (% real change pa), the balance of current-account/GDP, and all the technological indicators have high values (Table 3). Stable economic structures, as well as positive scenarios of future economic growth displayed by technological indicators, turn these countries into virtuous models of economic development. They are located in the north east corner, which includes countries such as Switzerland, the USA, Norway, Canada, Ireland, Great Britain, and Belgium.
- *LEG: Low Economic Growth.* Although their macroeconomic indicators show positive values, the technological indices are low, so that the foresight concerning their economic growth is low. Examples are some countries in the European Union.
- *HEG: High Economic Growth.* The main characteristics of these countries are positive indicators of economic growth, such as a very low rate of unemployment, a high value of Gross Domestic Expenditure on R&D (GERD) as a percentage of Gross Domestic Product (GDP), GERD per capita population (U$ Dollar at PPP), and total researchers per thousand labour force. Therefore, the trend of economic growth forecasts is going up, also thanks to the low cost of labour, due above all to

the exploitation of weaker social classes and to the low bargaining power of trade unions (or complete lack thereof). This typology includes some countries in Eastern Europe, such as Ukraine, as well as some Asian nations (Thailand and China).

- *HCR: High Country Risk* is characterised by the fact that the main economic and technological indicators are very low (Table 3). In fact, the GDP (% real change pa), current-account balance /GDP, and all the technological indicators have very low and/or negative growth. The unstable structures of the economic system, as well as a very low economic growth, expose these countries to the risk of economic-financial shocks. Examples are Argentina, Brazil, and other countries in Latin America (Clark and Kassimatis, 2004), as well as Asian nations (e.g.: Turkey and Sri Lanka).

Table 3 shows the arithmetic mean of economic and technological indicators of the four sets.

Table 3. Arithmetic mean of the indicators within the 4 groups

Arithmetic mean		GDP per head ($ at PPP)	GDP (% real change pa)	Government consumption (% of GDP)	Budget balance (% of GDP)	Consumer prices (% change pa; av)	Public debt (% of GDP)	Labour costs per hour (USD)
I	HES (NE)[1]	29628.73	2.780667	19.816	3.01	2.467667	57.16	19.62767
II	LEG (SE)[2]	23320.97	2.493667	20.67533	-0.899	2.827333	67.00033	13.421
III	HEG (NW)[3]	12466.28	4.399744	11.94051	-2.20077	4.349231	49.51641	4.222051
IV	HCR (SW)[4]	7221.111	2.966481	13.85315	-4.14778	11.36	52.40167	1.63463

Arithmetic mean		Recorded unemployment (%)	Current-account balance/GDP	Foreign-exchange reserves (mUS$)	Domestic Expenditure on R&D (GERD) as % of GDP	GERD per capita population (U$ Dollar at PPP)	Total researchers per thousand labour force
I	HES (NE)[1]	5.144667	4.008667	23828.67	2.3758	673.1042	8.3042
II	LEG (SE)[2]	8.166667	-2.228	22598.97	1.6017	403.3833	5.7958
III	HEG (NW)[3]	5.391282	5.844615	98468.1	2.9433	631.8167	7.9333
IV	HCR (SW)[4]	11.71741	-1.77444	12152.8	0.8253	98.2000	3.2600

1. *HES*: High Economic Stability (I quadrant or North East corner)
2. *LEG*: Low Economic Growth (II quadrant or South East corner)
3. *HEG*: High Economic Growth (III quadrant or North West corner)
4. *HCR*: High Country Risk (IV quadrant or South West corner)

V. Concluding remarks (to be improved)

This paper applies principal component analysis to develop a taxonomy of country performance and risk assessment based on leading economic and technological indicators. The purpose of this research is to integrate and extend the studies on countrymetrics based on multivariate approach. In fact, although the literature on this subject presents several approaches of countrymetrics based on statistics techniques, it lacks taxonomies based on multivariate analysis that provide synthetic information on the strategic behaviour of countries in the global market. This research fills a gap in the economic literature on countrymetrics, because it proposes a simple taxonomy of country based on principal component analysis.

The map (Figure 1) shows the strategic location of countries within its 4 quadrants. The first or north east corner includes all the countries with positive factors; the second or south east corner has positive x-axis values while y-axis has negative values. In the third corner or north west there are countries characterised by negative x-axis values and positive y-axis values, while the fourth or south west corner has a negative value of the factors. This analysis shows that some countries, which have had price shocks of different intensity (such as Argentina and, to a lesser extent, the Eurozone countries), are located in quadrant II. In these cases, if a corrective policy is not introduced, the real GDP decreases, prices increase, and the countries migrate towards the HCR area. In this situation, in order to change the country migration from the HCR area to the HES and/or HEG area, the monetary authorities may increase money supply, as a response to the price shock. This shifts the aggregate demand curve towards the outside, which reduces the real GDP. The increase in money supply amplifies price fluctuations, even though it reduces real GDP fluctuations. In case monetary authorities decide not to intervene, prices increase and the aggregate demand decreases, although afterwards a process of long-run equalisation begins: prices tend to go back to normal values and production reaches its full potential again. Therefore, shocks leading to an increase in prices force those responsible for economic policies to face a difficult choice: if GDP reduction is avoided, prices have less instability; if the rise of the inflation is slowed down, economic recession worsens (Hall and Taylor, 1993).

Even though the present study is based on historical series and on a static view of countries, it facilitates the identification of the performance and strategic behaviour of countries. The nations located in the north east or south east corner within the map of strategic placement display medium-high performances, which are hardly going to decrease in the short run or move towards risk areas (in other words towards the south west). In this case, governments can adopt stabilisation policies in order to strengthen economic stability and/or migrate upwards to reach the area of the most virtuous countries (with high performances and high economic growth). On the other hand, governments of countries located in the left section within the map of strategic placement (figure 1) should work towards the enactment of long-run economic policies as well as market labour, financial market, and fiscal reforms. These policies should enable the nation to quickly migrate towards the right area of the map and in a longer period of time towards the north east area (high performance regions). If the present analysis is repeated over time, it is possible to achieve a dynamic view (movements) of the economic and technological performance of each country, which can provide important information to evaluate the effectiveness of economic and research policies. The weakness of this research is that there is no way to guarantee that the principal components are the best regressors. Moreover, the map in figure 1 has an unusual feature: some nations like Argentina (placed along the border of the vertical axis) are located within the II quadrant, where there also are countries like Germany and France, which clearly have a different economic system. This anomaly is due to the fact that the map considers only two of the three principal components. Therefore, the boundaries of the clusters are not always extremely precise. Another limit of the research is the several missing value of technological data, which come form OECD Statistics (2004). For this reason it has not been possible to apply the PCA on technological indicators and the technological performance analysis, within the four groups, has been carried out on 23 countries only. However, this analysis proposes a taxonomy and map, which synthesise the strategic behaviour of countries and evaluate their economic and technological performance in a simple manner. This research improves the analysis of country assessment based on the multivariate approach, in particular principal component analysis. In the future, this classification scheme will be refined with the application of other methodologies, such as the 'network neural analysis' and 'Multi Criteria Decision Making' methods, in order to outline precise boundaries of the sets that ensure a better taxonomy of country performance and strategic behaviour.

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