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AN EMPIRICAL ANALYSIS OF THE ROLE OF CAPABILITIES IN NATIONAL INNOVATION SYSTEMS

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Abstract

The aim of this work is to study the role of capabilities in the national innovation systems of both developed and emerging countries, as well as their impact on economic growth. To do so, it uses factor analysis on 22 indicators and 50 countries to develop composite variables of social and technological capabilities. The results show that the development of technological capabilities is highly correlated with subsequent economic growth. However, the returns of the improvement of technological capabilities on economic growth will depend inversely on the distance to the world technology frontier.

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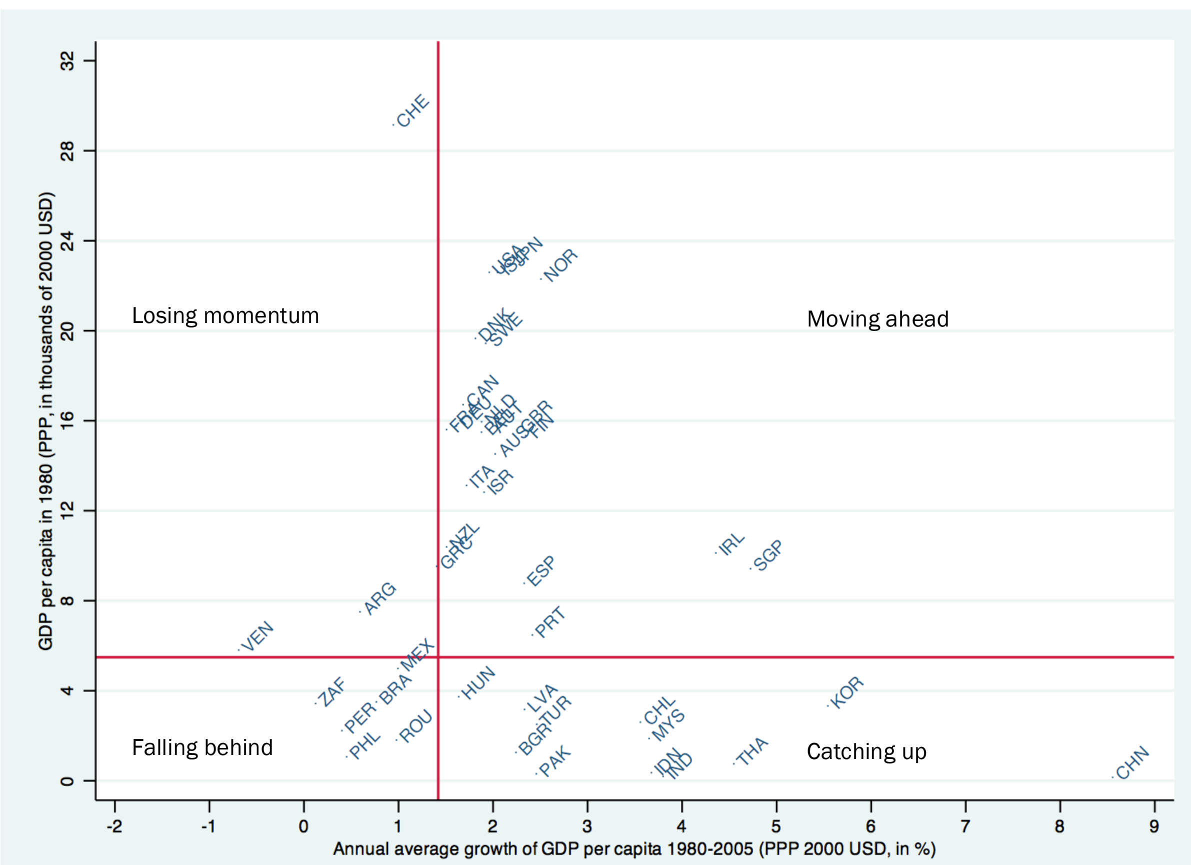
1. INTRODUCTION

Historically, successful catch-up has been associated with both the adoption of existing products and techniques in established industries – imitation – and with innovation. If all countries below the technological frontier catch up, convergence will necessarily follow; on the other hand, if only some countries catch up, while others fall behind, then the outcome with respect to convergence is not clear.

Empirical studies have shown that convergence is limited only to groups of countries, or 'convergence clubs' (Baumol, 1986). To illustrate this, Figure 1 presents differences in economic performance across countries, plotting growth in GDP per capita in the period 1980-2005 against its level at the beginning of the same period for the sample of 50 countries considered in this work. Then, four quadrants surge, in line with the terms coined by Abramovitz (1986): those countries with initial low per capita income and subsequent low growth that are "falling behind" from the rest; countries with high initial income per capita that had low growth during the following years,

Figure 1: Convergence and divergence in GDP per capita over the period 1980-



which are considered to be “losing momentum”; initially poor countries that managed to grow fast, “catching up” with the developed countries; and initially rich countries that grew fast, “moving ahead” from the rest of the economies.

Then, it is central for economic growth analysis to explain the differences between the countries’ growth rates through the conditions for successful catch-up; to be able to exploit technology, countries need to develop the necessary capabilities for doing so. But, what are those conditions or capabilities that firms, industries and countries need to develop in order to escape the low development trap? By using the methodologies followed by Archibugi and Coco (2005) and Fagerberg and Srholec (2008), the aim of this work is to study the role of capabilities in the national innovation systems of both developed and emerging countries, as well as their possible impact on economic growth.

An adequate quantification of current and lagged levels of technological and social capabilities is important to understand why some countries innovate and have a better economic performance than others. This work empirically identifies, through factor analysis, five dimensions of capabilities: technological capabilities, three central features of social capability – following Abramovitz (1986): the political system, market freedom, and openness to international market – and a common feature between technological and social capabilities: financing. A central finding of this study is that the development of technological capabilities is highly correlated with subsequent economic growth, but the returns inversely depend on the distance to the world technology frontier.

The remainder of this work proceeds as follows. Section 2 discusses earlier studies on growth theory, catch-up, national innovation systems and capabilities, as well as studies that link the theoretical considerations of capabilities with empirical frameworks. Section 3 briefly lists the countries and indicators used in the empirical part of this study, as well as their link with the theoretical framework. Section 4 presents the results of factor analysis, as well as their economic interpretation and the relation between the resulting factors and economic growth. Section 5 compares both the statistical approach and the consistency of the technological capability measure found in this study to other existing indicators in the literature. In Section 6, a battery of econometric methods is used to further explore the relationship between both technological and social capabilities and economic growth. Finally, Section 7 concludes.

2. LITERATURE REVIEW

2.1. FORMAL GROWTH THEORY

Over the 1950s and 1960s, the main focus of neoclassical economists was on the relationship among income distribution, capital accumulation and growth, not on technology. Neoclassical growth theory, as exhibited by Robert Solow's model, assumes technology to be a public good, i.e. something that is available to everyone everywhere free of charge. Then, according to this theory, all countries share the same pool of technology.

Based on this idea of technology, and to allow for long-run growth in GDP per capita, Solow added an exogenous term called "technological progress". Under this assumption, GDP per capita in all countries will grow at the same rate of technological progress in the long run. Therefore, differences in per capita growth across countries can only be explained by "transitional dynamics", due to disparities in the initial conditions.

Then, the long-run rate of growth is exogenously determined, and economies will supposedly always converge towards a steady state rate of growth that depends only on the common rate of technological progress, factor accumulation, and the rates of labour force growth and savings. Since empirical research showed that this approach explained little of the observed differences, researchers started to consider other explanatory variables, such as the existence of "technology gaps" across countries, implying another interpretation of technology as less public and less neutral.

On the other hand, empirical studies on economic growth over the 1950s and 1960s endeavoured to growth accounting, i.e. decomposing growth of GDP. But, in their attempts to identify the contribution from technology to economic growth and to better distinguish it from other sources, growth accountants were confronted by considerable struggles.

Abramovitz (1956) found a major part of productivity growth was explained by an unidentified total factor productivity (TFP) growth. This TFP factor was defined by Solow as a residual that describes empirical productivity growth – widely known in the growth literature as the "*Solow residual*" – since it is the part of growth that cannot be explained through capital accumulation or the accumulation of other traditional factors, such as labour or land.

Nevertheless, identifying TFP with technology became a main issue since it is not easy to disentangle factor accumulation from technological progress. Because of this, during the 1980s and 1990s the interest in the role of knowledge – i.e. technology – in economic growth raised, especially with the emergence of the "new growth theory". This theory states that differences in economic growth and development across countries are the outcome of endogenous knowledge accumulation within borders. Besides, these models not only endogenise technological progress, but they also relate technological change to the underlying market structure. Contrary to neoclassical growth models, endogenous models imply that "small differences in policies, technological opportunities or other characteristics of societies will lead to permanent differences in long-run growth rates" (Acemoglu, 2008, p. 435).

Therefore, according to this approach, long-run economic growth should be expected to depend on economic incentives to innovation, such as: strong intellectual property rights enforced by a robust legal system, supply of needed skills and financial availability. Additionally, Grossman and Helpman (1991) propose that openness to trade and foreign investment should be considered essential for countries to catch-up, since this might help them to overcome the disadvantages of scale. However, scale effects are not very plausible empirically and have been criticized by many authors.

2.2. CATCHING UP

Although neoclassical growth models predict that in the long run international growth rate differentials cannot exist, the economic history of the 20th century showed an increasing gap between rich and poor countries (Lucas, 1988). Due to these contradictions, a technology-gap approach started to develop within the economic growth debate.

Contrary to the traditional neoclassical theory, technology-gap theorists consider technological differences to be the prime source of cross-country differences in GDP per capita, with know-how embedded in organizational structures; this last consideration understands technology as less public, making it more difficult and costly to transfer (Fagerberg, 1994).

Catching up refers to the hypothesis that "countries with relatively low technological levels are able to exploit a backlog of existing knowledge and therefore attain high productivity growth rates, while countries that operate at (or near to) the technological frontier have less opportunities for high productivity growth" (Verspagen, 1991, p. 359). In other words, it denotes the reduction of the gap in productivity between a leader country and a group of followers. Fagerberg (1994) argues catching-up is a post World War II phenomenon, since the gap in labour productivity between the United States and the mean of other fifteen industrialized countries has been shrinking since around 1950.

Then, theoretically, as Abramovitz and David state,

> "Economic growth as we have known is not a balanced, steady-state affair in essence. […] Rather, central features of the historical process of growth […] may be viewed as part of a sequence of technologically induced traverses, disequilibrium transitions between successive growth paths" (Abramovitz & David, 1973, p. 429).

Several empirical studies that investigate the strength of the catching-up hypothesis conclude there is a strong negative correlation between growth rates and initial per capita income, but many authors show catching-up is not a global phenomenon. Baumol comes to the conclusion that "rather than sharing in convergence, some of the poorest countries have also been growing most slowly" (Baumol, 1986, p. 1079); and De Long (1988) argued an "ex post selection bias": the long-run convergence for the richest countries today doesn't hold for the richest countries of the previous century.

Baumol, Batey and Wolff (1989) presented a simple model of cross-country growth including the potential for catch-up and education. After expanding the sample used by De Long to all countries for which data were available, the authors showed there is little support for convergence when all developing countries are included, and argued that convergence is confined to groups of countries, or "convergence clubs", in specific time periods.

Then, the catch-up hypothesis regained significance, but conditional on educational efforts; out of this debate, Fagerberg deduces that "a simple catch-up model with one independent variable is not sufficient to explain differences in growth" (Fagerberg, 1994, p. 1160). However, he claims that the rate of productivity growth of a follower also depends on other factors that differ across countries, apart from the gap in productivity, such as appropriate economic and institutional characteristics.

The first attempts to conceptualise this institutional notion were developed by the economic historian Alexander Gerschenkron in his 1962 book “Economic backwardness in historical perspective”, with the study of relatively backward economies, such as Germany, France and Russia, during the 19th century.

Contrary to the Marxian generalisation, according to which it is the history of advanced industrial countries that traces out the path for development for the more backwarded countries, Gerschenkron stated that the development of a backward country might tend to differ fundamentally from that of an advanced one. Moreover, he proposed that, in a number of important historical illustrations, industrialisation processes in a backward country showed substantial “differences in the speed and character of industrial development [that] were to a considerable extent the result of application of institutional instruments for which there was little or no counterpart in an established industrial country” (Gerschenkron, 1962, p. 7). The objective of these institutional instruments would be to mobilize resources to endeavour the necessary changes required by modern technology.

In accordance with Gerschenkron, the extent of the variation in industrial development depends directly on the “natural industrial potentialities” of these countries, such as their endowments of natural resources and certain institutional arrangements; certain “non-competitive” institutional arrangements, including long-term relationships between firms and banks, large firms and state interventions; and the degree of “relative backwardness”, seen as the backlog of technological innovations.

About this last point, he considered that applying the most modern and efficient techniques, through borrowed technology, was one of the main factors that could guarantee a high speed of development in a backward country entering the stage of industrialisation. Then, the institutions and policies that are appropriate to relatively backward countries should encourage investment and technology adoption, even if this comes with market rigidities and a less competitive environment (Acemoglu, Aghion, & Zilibotti, 2006).

Under the Gerschenkronian viewpoint, technology transfer is very demanding in terms of infrastructure; and market forces will be unlikely to succeed if left alone; then, some degree of active intervention by outsiders – i.e. private or governmental organisations – is necessary.

In this approach, firms are seen as key players, characterized by different combinations of intrinsic capabilities – including technological know-how – and strategies; and technological change is the result of both innovation and learning activities within organizations, and their interaction with their environments (Fagerberg, 1994).

Country-specific factors are assumed to affect the technological change process, in a sense that Nelson and Wright (1992) coined as “national technology”, with technologies having a different national character. Therefore, many authors consider countries as separate systems, each with its own dynamics and characteristics, calling them “national innovation systems” in the related literature.

With the nation as the centre of this analysis, the main assumption of this approach is that history, culture, language and institutions connect individuals, firms and organizations, with important consequences for technological progress. If this assumption loses its validity, this approach might miss its importance. Both the “national innovation systems” approach and the impact of globalisation in them are discussed in more detail in the next section.

2.3. NATIONAL INNOVATION SYSTEMS

The concept “national innovation systems” was first used by Christopher Freeman in his 1987 book “Technology Policy and Economic Performance: Lessons from Japan”; this term includes “all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations” (Edquist, 2004, p. 183).

Considering the broad aspects on this approach, there is no single accepted definition of a national system of innovation, but there are some definitions that highlight most of the main characteristics involved in this approach (See Freeman [1987], Metcalfe [1995] and Nelson & Rosenberg [1993]). Based on these definitions, this work will consider *national innovation systems* as the set of interrelated institutions and organisations whose interactions and activities determine the creation, importation, modification and diffusion of new technologies.

According to the OECD (1997), this approach has gained importance thanks to three main factors: its recognition of the economic importance of knowledge, the increasing use of systems approaches, and the number of institutions involved in knowledge generation. I will explain these factors in more detail.

Economic importance of knowledge

The national innovation systems approach focuses on the flows of technology and information among people, enterprises and institutions as key to the innovative process. Then, the study has focused on improving the performance in knowledge-based economies, defined as “economies that are directly based on the production, distribution and use of knowledge and information” (OECD, 1996, p.7). Since economic activities are increasingly knowledge-intensive, “investments in knowledge, such as in R&D, education and training, and innovative work approaches are considered key to economic growth” (OECD, 1997, p.11).

Increasing use of systems approach

The systems approach can be useful for the creation of theories about relations between specific variables; the use of this approach is opposed to the linear model of innovation, which considers new innovations and technologies as a direct result of “scientific inputs”, where science is the originator of innovation. On the other hand, national innovation systems consider innovation as a result of the interaction between many actors, such as firms, universities and government agencies, with technical change as a result of “feedback loops”.

Edquist (2004) highlights the strengths and weaknesses of the systems of innovation. Among the strengths, he considers that this approach:

- Places innovation and learning processes at the centre of focus.
- Adopts a holistic and interdisciplinary perspective.
- Employs historical and evolutionary perspectives, making the notion of optimality irrelevant.
- Emphasizes interdependence and non-linearity.
- Emphasizes the role of institutions.

On the other hand, among its weaknesses, he states the innovation systems approach “is still associated with conceptual diffuseness” and that it doesn’t have a status as a formal theory, considering it instead an “approach” or a “conceptual framework”, due to the relative absence of well-established empirical regularities.

Institutions involved in knowledge generation

The policies and programs of national governments, the nation's legal system and the existence of a shared culture and language, among other factors, define an "inside and outside" that can affect technical advance. Furthermore, national boundaries and differences tend to define national innovation systems; then, each country has its own institutional profile.

Summing up this last idea, Nelson and Rosenberg use the term "*technonationalism*", which combines "a strong belief that the technological capabilities of a nation's firms are a key source of their competitive prowess, with a belief that these capabilities are in a sense national, and can be built by national action" (Nelson & Rosenberg, 1993, p. 3). This "*technonationalism*" has raised the current strong interest in national innovation systems and in the scope and approach to which these national differences explain variations in national economic performance.

Although technological communities have become transnational thanks to globalisation, there still remain some striking disparities between systems of countries in comparable economic settings. These disparities are based in differences in national histories and cultures such as, for example, the timing of a country's entry into the industrialisation process; then, these have shaped national institutions, laws and policies.

Despite the theoretical importance of this approach, there is no agreement on how it should be empirically studied. However, according to Fagerberg and Srholec (2008), there have been some attempts by trying to measure a country's innovation system through the number of patents that its population generates; nevertheless, as Fagerberg (2006, p.11) points out, "patents reflect invention, not innovation": for countries below the technology frontier – such as developing countries – most of their innovative activities would get unrecognized under this approach.

2.4. CAPABILITIES

In accordance with Gerschenkron, catch-up is not automatic, but the result of significant effort and institution building. Following this idea, over the next section a review will be made on the historical study of capabilities under different perspectives and terminologies, along with their significance to economic activity, since they operationalize the Gerschenkronian hypothesis of appropriate economic and institutional characteristics.

2.4.1. SOCIAL CAPABILITY

Abramovitz (1986) points out that the technological backwardness of a country not only depends on the level of technology embodied in its capital stock, but also in societal characteristics and the country's past failure to achieve the level of productivity of more advanced countries. Following Ohkawa and Rosovsky (1973), Abramovitz calls these characteristics "social capabilities", which are collective competences related to "what organizations in the private and public sectors are capable of doing and how this is supported (or hampered) by broader social and cultural factors" (Fagerberg & Srholec, 2008, p. 1418).

Abramovitz concerns with the notion of a trade-off between specialization and adaptability: The level of education in a country and the nature of its commercial, industrial and financial organizations might be well designed to capitalise the existing technology, but they may be less suitable to adapt to change. Nevertheless, technological opportunity might press for change, and countries can learn to modify their institutions. It is important to also take into consideration that social capabilities depend on more than education and the organization of firms: other aspects of economic systems count as well, such as a country's openness to competition and the establishment and operation of new firms and goods.

Then, a country's potential for high rates of economic growth is strong when it is "technologically backward but socially advanced", as Abramovitz claims; and a country's potentiality for productivity via catch-up can be defined by a combination of technological gap and social capability. Some aspects of social capability that he emphasized (Abramovitz, 1986; Abramovitz, 1994) are: technical competence – measured as level of education; experience in the organization and management of large scale enterprises; financial institutions and markets capable of mobilizing capital on a large scale; honesty and trust; and the stability of government and its effectiveness in defining and enforcing rules, and supporting economic growth (Fagerberg & Srholec, 2008).

2.4.2. TECHNOLOGICAL CAPABILITY

Intrigued by South Korea's rise from being one of the poorest countries in the world to an industrialised powerhouse in only four decades and following Cohen and Levinthal's viewpoint, Linsu Kim developed the book "Imitation to innovation: The dynamics of Korea's technological learning". In the introduction chapter, he coined the term "technological capability", which refers to "the ability to make effective use of technological knowledge in efforts to assimilate, use, adapt and change existing technologies" (Kim, 1997, p. 4).

The definition of technological capabilities by Kim is quite similar to that of 'absorptive capacity' by Cohen and Levinthal (1990), and Kim (1997) uses the two concepts interchangeably. But, unlike Cohen and Levinthal, Kim identifies three elements in the technological capability:

- Production capability, which refers to numerous technological capabilities required to operate and maintain production facilities;
- Investment capability, that are the abilities required for expanding capacity and establishing new production facilities; and,
- Innovation capability, that consists of abilities to create and carry new technological possibilities through to economic practice.

2.5. EMPIRICAL STUDIES

Due to the difficulty faced when trying to link the theoretical and the empirical approaches, only a few empirical works on the role of capabilities in economic growth were found. Nevertheless, these works present a suitable approach to the study of this area and will be reviewed closely. Table 2 summarizes the comparative analysis of these empirical studies.

2.5.1. ADELMAN & MORRIS (1965)

Adelman and Morris analyse the socio-political and institutional influences upon economic growth to gain more precise empirical knowledge about the extent and nature of interdependence of economic and noneconomic aspects of the growth process. To do so, the techniques of factor analysis were applied to GNP per capita income and 22 indicators reflecting the social and political structure of 74 less-developed countries in the period 1957-1962. The results of this analysis showed that two thirds of inter-country variations in the level of economic growth are associated with differences in noneconomic characteristics.

As the authors suggest, the results of the factor analysis don't demonstrate that economic growth is caused by socio-political transformations, and neither indicate that variations in development levels determine patterns of social and political change; rather, they suggest the existence of "a systematic pattern of interaction among mutually interdependent economic, social and political forces, all of which combine to generate a unified complex of change in the style of life of a community" (Adelman & Morris, 1965, p. 557).

Taking advantage on the fact that factor analysis can use a relatively large number of intercorrelated variables as data inputs, Adelman and Morris used a broad selection of indicators reflecting: social characteristics, to depict important aspects of social changes associated with urbanisation and industrialisation; political indicators, to summarize leading aspects of the growth of modern nation states; and other characteristics, such as the quality and orientation of political administration and leadership; and the importance of key interest groups within the nation.

The procedures used in defining indicators and in ranking countries differed for various types of country characteristics, with three categories distinguished: 1, those for which classification could be based only on published statistics; 2, those for which it was necessary to combine statistical and qualitative elements; and 3, those which were purely qualitative in nature. These last categories show the problem researchers faced during those years due to the lack of available and reliable statistical databases.

Once the classification of countries – according to various characteristics – was completed, each of the 74 less-developed countries was given a letter score according to the American grading system, going from A+ to D-, with respect to the 22 social and political indicators, that were converted to a linear system going from 100 (maximum value) to 0 (minimum value).

Out of this statistical analysis, the authors identified four factors:

- Factor I may be interpreted to represent the "processes of change in attitudes and institutions associated with the breakdown of traditional social organisation". Levels of economic development are closely associated with the degree of specialisation and integration of social structure, with the rise of the middle class identified as an essential feature to the creation of an institutional framework favourable to economic change.

- Factor II describes variations among countries in political systems. The coefficients resulting from the factor analysis indicate that a typically Western configuration of political traits is generally associated with higher average income.
- Factor III is related to "the character of leadership and the nature of leadership strategies", with two extreme considerations: at one end are leaders with strong attachment to the preservation of a traditional society, against the ones that are intensely nationalistic and committed to industrialisation and state direction.
- Factor IV shows a positive relation between per capita GNP and social and political stability, implying the absence of social tensions and political instability is a prerequisite for sustained economic growth.

Additionally, the authors developed similar regional studies, with Africa, Latin America, and Near and Far East as objects of study. Their results support the findings of the over-all analysis and show that

> "The role of social aspects of the industrialisation-urbanisation process is overwhelmingly important for low income economies in which the absorptive capacity is sharply limited by the inhibiting nature of the social structure" (Adelman & Morris, 1965, p. 577).

Their pioneering methodology to study the effect of non-economic variables in economic growth and development opened a new line of investigation in economics. However, choosing a numerical scale for qualitative scales is somehow an arbitrary decision; and, due to the lack of data that authors faced, there could be several measurement biases that needed to be considered.

2.5.2. TEMPLE & JOHNSON (1998)

Temple and Johnson introduce this paper by claiming researchers sought the origins of long-run growth in the wrong places, neglecting the role of social capabilities in economic growth. To address this, they show that the index of socioeconomic development constructed by Adelman and Morris (1968) could have helped researchers to make better forecasts of long-run growth rates; they do so by gathering enough evidence that fast growth is partly the outcome of favourable social arrangements. Nevertheless, Temple and Johnson use Adelman and Morris' data without taking advantage of the increase of available statistical information to correct their arbitrary measurement of qualitative variables.

After analysing Adelman and Morris' work, the authors highlight the close relation between social development – represented by a social development index, or SOCDEV – and income per capita. Although the relation of causality is uncertain, they argue that a higher level of social development is likely to be reflected in higher investment and lower population growth, and economic development brings widespread social changes. Besides, the authors consider that "higher levels of socioeconomic development are associated with higher investment rates in physical and human capital, with more productive investments, or with a greater ability to assimilate technology from abroad".

After this, they examine the direct effect of social arrangements on growth, acting through total factor productivity. To study this, they work with a standard regression specification based on Mankiw, Romer and Weil (1992):

$$\ln\frac{Y(t)}{L(t)} - \ln\frac{Y(0)}{L(0)} = \theta \ln A(0) + G(X) + \theta\frac{\alpha}{1-\alpha-\beta}\ln(s_k) +$$

$$+\theta\frac{\beta}{1-\alpha-\beta}\ln(s_h) - \theta\frac{\alpha+\beta}{1-\alpha-\beta}\ln(n+g+\delta) - \theta\ln\frac{Y(0)}{L(0)}$$

where $Y(t)/L(t)$ is per capita income at time t; $\theta = 1 - e^{-\lambda t}$, where λ is the rate of convergence; s_k and s_h are the rates of physical and human capital accumulation; α and β are technology parameters, n is population growth, g is efficiency growth, δ is the rate of depreciation, $A(t)$ is the level of efficiency at time t, and $G(X)$ is the rate of efficiency growth as a function of the variables related to social arrangements.

Estimates of this equation suggest that the Adelman and Morris index is a useful predictor of subsequent growth performance, even when subsequent information – such as investment, schooling and population growth – is used; however, the direct effect of this index is not so strong when regional dummies are included. After these results, authors suggest SOCDEV is a robust determinant of economic growth, with its effect operated partly via total factor productivity (TFP) growth.

Nevertheless, some criticised that the construction of the Adelman and Morris index only captured partially the notion of social capability, and that it failed to show why society might matter, since it used only a range of economic and social variables that didn't measure the theoretical construction of social capability. To address these criticisms, Temple and Johnson concentrate on just five of the indicators that Adelman and Morris used to construct their index. They found that one of them, the extent of mass communications in the early 1960s – based upon a composite index of newspapers in circulation and radios in use – has a particularly strong correlation with subsequent growth, and seems to have a direct effect on total factor productivity growth as well as on factor accumulation, even after testing for robustness.

2.5.3. ARCHIBUGI & COCO (2005)

In this article, Archibugi and Coco compare the methodologies and results of six measures of national technological capabilities provided by the World Economic Forum (WEF), the United Nations Development Program (UNDP), the United Nations Industrial Development Organisation (UNDO), the World Bank (WB) and the RAND Corporation; along with Archibugi and Coco's own measure of technological capability, ArCo.

Filling the need of new and improved measures of technological capabilities on the performance of nations to understand economic and social transformations, these organisations and researchers have developed indicators and measures, taking advantage on the improvement of statistical sources and tools.

Archibugi and Coco (2005) hold that the notion of national innovation systems "requires identifying the qualitative as well as the quantitative differences across countries" and that it assumes each national system is the result of a large number of institutions and of geographical components. However, measuring technological capabilities is more complicated than other economic and social indicators, due to the heterogeneous nature of the different components of technology.

Relating to the nature of technology, the authors consider the measurement of technological capabilities should not only include indicators of the generation of inventions and innovations, but also of their application and dissemination; and it is assumed that the various components of technological capabilities are complements, not substitutes.

The five measures of technological capability analysed in this work, and summarised in Table 1, are:

- The **WEF Technology Index** developed by the World Economic Forum. It includes three main categories of technology for 102 countries: innovative capacity, ICT diffusion and technology transfer. An important consideration of this index is that it uses an asymmetric measurement of technology – giving a lower weight to the indicators of innovative capacity – since many countries derive competences from technology use and imitation, rather that production and innovation.
- The **UNDP Technology Achievement Index**, reported in the Human Development Report by the United Nations Development Program (UNDP). Here, authors consider four dimensions of technology achievement for 84 countries: creation of technology, diffusion of newest technologies, diffusion of oldest technologies and human skills.
- The **ArCo Technological Capabilities Index (ArCo)**, developed by Archibugi and Coco in their 2004 article "A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo)", analysing 162 countries and taking into account four dimensions of technology: innovative activity, technology infrastructure, human capital and import technology. This fourth component is an important contribution to the literature, since it is based on the assumption that "an important source of technological capabilities is also represented by the possibility of a country to access technology developed elsewhere" (Archibugi & Coco, 2005).
- The **Industrial Development Scoreboard**, from the United Nations Industrial Development Organisation (UNIDO), that collects a group of indicators for 87 countries under four categories: technological effort, competitive industrial performance, technology performance and technology imports. It is important to highlight this scoreboard does not produce a synthetic indicator, due to the scepticism towards the compression of many variables into a single measure.
- The **Science and Technology Capacity Index (STCI)**, by the RAND Corporation, for a set of 76 countries with eight indicators aggregated into three categories: enabling factors, resources and embedded technology. In this index, the outcome depends on the weights assigned each category, which is an important disadvantage to consider.

Table 1: Comparison of measures of technological capabilities

Measure	WEF	UNDP	ArCo	UNIDO	RAND
Name	WEF Technology Index	UNDP Technology Achievement Index	Arco Indicator of Technological Capabilities	UNIDO Industrial Development Scoreboard	Science and technology
Innovation	Patents at USPTO and survey data	Receipts of royalty and license fees, national patents	Patents at USPTO, scientific articles	Enterprises financed R&D, patents at USPTO	Patents at USPTO, scientific articles, R&D expenditure
Diffusion	Internet, PCs, telephone, survey data, non-primary exports, survey question	Internet hosts, medium and high-technology exports, telephone, electricity consumption	Internet, telephone, electricity consumption	Telephone main lines, FDI, foreign royalty payments, capital goods	Number of institutions, internationally co-authored papers
Human capital	Tertiary enrolment	Years of schooling, tertiary science enrolment	Scientific tertiary enrolment, years of schooling, literacy rate	Tertiary technical enrolment	Tertiary science enrolment, number of scientists and engineers
Aggregation	Asymmetric weighted mean	Simple mean	Simple mean	No synthetic indicator	Weighted mean
Number of countries	102	84	162	87	76
Year	1997, 2003	1995, 2000	1990, 2000	1998	2000

Source: Archibugi and Coco (2005)

After comparing the ranking of countries of each measure, authors conclude only a few significant differences emerge. The similarities under each approach reflect certain consensus on the nature of technology, despite the differences in the availability of statistical data.

One of the main considerations of this paper is that none of these attempts have tried to weigh and combine the various components using a statistical technique, such as factor or principal component analysis; instead, each author has decided the relative importance of every component of technological capabilities, leaving this as an arbitrary decision.

2.5.4. FAGERBERG & SRHOLEC (2008)

In this paper, Fagerberg and Srholec (2008) empirically analyse the capabilities needed to succeed in economic growth, following Adelman and Morris (1965, 1967), and Temple and Johnson (1998), by using factor analysis on 25 indicators for 115 countries from the 1992-2004 period to determine the most important elements among the various indicators used.

The analysis leads to the selection of four factors – that jointly explain 74% of the total variance – as the different dimensions of capabilities:

- Factor I, called "development of innovation system" since it loads highly on several indicators associated with "technological capability": patenting, scientific publications, ICT infrastructure, ISO 9000 certifications and access to finance. It is important to highlight that it also correlates highly with education, which is the main measure of social capabilities, emphasizing the importance of education for both capabilities. The correlation between this factor and the log of GDP per capita is very high, 86%,
- Factor II, coined "quality of governance", loads highly with aspects related to a well-functioning judicial system, little corruption and a favourable environment for business. Although its correlation with the log of GDP per capita is high, with 57%, it is not as strong as the first factor.
- Factor III loads high on indicators reflecting the "character of the political system". As Fagerberg and Srholec point out, "countries with political systems that are close to those of the Western world, rank high on this dimension, while countries with systems that differ from Western democratic ideals, get a low mark". However, this trait is not closely correlated with levels of development, with distinctly authoritarian regimes doing rather well economically.
- Factor IV correlates highly with only two indicators: imports of goods and services, and foreign direct investments. Then, it is called "degree of openness of the economy". Although this is a factor deemed by the "new growth theory", it does not correlate with economic growth, irrespective of whether country size is controlled for or not.

Simple correlations might hide more complex relationships; subsequently, Fagerberg and Srholec explore cross-country differences in capabilities to try to understand countries' economic growth. Authors perform a multivariate regression of the four capabilities identified and the GDP per capita; and, in addition to the capabilities already mentioned, they include a set of indicators reflecting differences in geography, nature and history. Besides the ordinary least squares estimate, they test for robustness with iteratively reweighted least squares and, to identify the specification with the best statistical properties, authors use a (backward) stepwise regression.

The empirical analysis suggests that, in order to succeed in catch up, a well-developed innovation system is necessary. Among their findings, authors realize that factors related to geography, nature and history debilitate the development of a well-working innovation system. Besides, they find that the political system – and what they call "the degree of westernization" – has a diametrically opposite effect in poor and rich economies: a significantly negative effect turns to a significantly positive impact when only the richest half is included; this might be explained with the degree of diversity among the poor countries in how their economies work, or with a measurement problem.

Finally, authors find that the argument that differences in openness matter much for development is quite weak, which is consistent with the findings of Rodrik et al (2004). This result doesn't hold when a robust regression technique to test for the impact of outliers – iteratively reweighted least squares – is applied, with changes in openness over time having a modest positive effect in economic growth.

Fagerberg and Srholec conclude "the picture that emerges from this study is one of a global knowledge-based economy with strong elements of endogenous growth" and that "countries that succeed in developing and sustaining strong innovation capabilities and well-functioning systems of governance do well economically while those that fail tend to fall behind" (Fagerberg & Srholec, 2008, p. 1427).

Table 2: Comparative analysis of empirical works on capabilities.

Authors	Adelman & Morris (1965)	Temple & Johnson (1998)	Archibugi & Coco (2004)	Fagerberg & Srholec (2008)
Methodology	Factor analysis	Factor and econometric analysis	Index	Factor and econometric analysis
Countries	74 (less-developed)	74, same as Adelman & Morris [AM].	162 countries.	115 countries.
Capabilities measured	Social capability	Social capability	Technological capability	Social and technological capabilities
Indicators of social capability	22, including: Mass communication and literacy, modernization and cultural homogeneity, political rights and civil liberties, extent of social mobility, among others.	Same 22 indicators as AM. Then, they focus on 5 indicators: character of basic social organization, modernization of outlook, communications, schooling, and middle class.	Not considered.	10, measuring political rights, civil liberties, quality of governance, executive and legislative competitiveness, democracy, among others.
Indicators of technological capabilities	Not considered.	Not considered.	8: Patents, publications, internet users, phone lines, electricity consumption, tertiary enrolment, schooling, and literacy rate.	13, including: patents, publications, ISO9000 certifications, phone lines, internet users, FDI, merchandise imports, domestic credit and schooling.
Factors/Indexes	4 factors: Breakdown of traditional social organization, political system, character of leadership, and social and political stability.	1 index of social capability based on the 5 indicators on which they focused.	1 index: Indicator of technological capabilities (ArCo)	4 factors: Innovation system, political system, governance and openness.

3. SELECTION OF COUNTRIES AND INDICATORS

3.1. SELECTION OF COUNTRIES

Since the aim of this work is to study the role of capabilities in the economic growth of both developed and emerging countries, a selection of countries was done considering that coverage on both time and country was available. Unlike Fagerberg & Srholec (2008), this study focuses on the role of social and technological capabilities in developed and emerging countries, with the special consideration of the role of research and development expenditure in their technological capabilities and subsequent economic growth. To do so, the screening was narrowed to a selection of 50 countries:

- **OECD members**, considered high-income countries with high development, and are regarded as high-income economies. 33 out of 34 members – Luxembourg was excluded – were considered: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, South Korea, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
- **Emerging countries**, considered nations with social or economic activity in the process of rapid growth and industrialisation. This study considers the 23 countries in the IMF list of emerging countries (some of them are also OECD members): Argentina, Brazil, Bulgaria, Chile, China, Estonia, Hungary, India, Indonesia, Latvia, Lithuania, Malaysia, Mexico, Pakistan, Peru, Philippines, Poland, Romania, Russia, South Africa, Thailand, Turkey and Ukraine.

3.2. SELECTION OF INDICATORS

Following Fagerberg and Srholec's (2008) methodology, a broad selection of indicators for the economic, social and political structures of the fifty countries was considered for this study, with indicators expressed as three-year-averages over two periods: an initial one, 1992–1994, and a final one, 2002–2004, following the existing growth literature. These periods were chosen due to data availability, although a broader period would be more suitable for economic growth analysis. Besides, some data was missing, so it had to be estimated using information on other countries, years and indicators.

Based on the notions of 'social capability' (Abramovitz, 1986), 'technological capability' (Kim, 1997) and 'absorptive capacity' (Cohen & Levinthal, 1989), and in the measures of technological capabilities analysed by Archibugi and Coco (2005), an overview of the indicators chosen to measure these aspects is presented. Appendix A presents a brief overview of definitions, sources and coverage of the indicators used.

3.2.1. INDICATORS OF TECHNOLOGICAL CAPABILITY

The generation of technology and innovation, captured by the 'innovation capability' of countries, as Kim coined it, can be measured in several ways. This study takes into consideration four aspects of science, research and innovation: research and development (R&D) expenditure, patents, scientific publications and international production quality standards.

R&D expenditure measures the resources used in the generation of new products and processes; besides, R&D intensities can be compared across countries by taking into account the R&D/GDP ratio, and is nuclear to new growth theory models as a source of economic growth, as Cohen and Levinthal (1989) have stated in their 'absorptive capacity' concept. Nevertheless, due to the lack of data for most countries, it hasn't been considered for empirical analysis on the role of capabilities. However, all countries considered in this study have available information on R&D expenditure for the period of time studied in this analysis, and it will be considered as a variable to study technological capabilities.

Although patents and scientific articles have been considered as measures of invention, not innovation, they are taken as good proxies of technology creation in a country. However, it is important to take into account that both indicators present variations in quality and sectorial distributions that vary from country to country. To avoid problems of measurement consistency, this work will only take into account patents granted by the United States Patent and Trademark Office (USPTO), and scientific publications covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI).

Since it is widely argued in the national innovation systems literature that scale effects can be reverted through openness to international markets, which may also enable technology transfer, two channels of international technology transfer are taken into account to measure openness: trade and foreign direct investment, measured through merchandise imports and the foreign direct investment inward stock, respectively. To avoid country-size bias, and following Fagerberg and Srholec (2008), both indicators were measured orthogonal to country size, by regressing them on the log of land area and taking the residuals as new measures.

In order to capture the 'production capability' (Kim, 1997) and following Fagerberg and Srholec (2008), this study considers the adoption of quality management systems through the number of firms in the country with ISO 9000 certifications, since "it is increasingly seen as a requirement for firms supplying high quality markets, and is […] likely to reflect a high emphasis on quality in production" (Fagerberg & Srholec, 2008, p. 1420).

To measure technology diffusion, three indicators of information and communications technologies (ICT) were chosen: fixed and mobile phone subscribers, Internet users and personal computers. It is important to highlight that these measures may also capture the current extent of mass communications, which was a strong predictor of subsequent economic growth in Adelman and Morris' analysis.

Finally, on the frontier between technological and social capabilities, we find two main aspects: financing and human capital. Gerschenkron argued on the importance of the financial system to mobilize resources for catching-up, and Abramovitz discussed the significance of highly skilled population also to catch-up. To take into account both viewpoints, this work considers the amount of domestic credit to private sector and the capitalization of companies listed in national capital markets for the financing aspect; and the rates of enrolment in secondary and tertiary education as human capital indicators.

3.2.2. INDICATORS OF SOCIAL CAPABILITY

As seen in the previous literature review, it is widely emphasised in the national innovation systems literature that technological advances in industry are significantly influenced by several external factors resulting in specific innovation systems. As it was reviewed before, Abramovitz considered social capabilities to depend on more than technical competence – measured as level of education – and the organization of firms; instead, other aspects of economic systems count as well, such as: a country's openness to competition; the establishment and stability of government; its effectiveness in defining and enforcing rules, as well as supporting economic growth.

To take into account empirically these social and cultural factors considered in Abramovitz's 'social capability', this study tries to capture both the importance of institutions and the effectiveness of law enforcement through indicators that measure the type of political system and government attitudes toward markets.

To estimate the type of political system, six indicators commonly used in the political science and institutional literature (Acemoglu & Johnson, 2005; Rodrik, Subramanian, & Trebbi, 2004) were chosen: the degree of democracy (vs. autocracy); the extent of separation of powers; the competitiveness of elections into both executive and legislative branches of government; and the degree of both political rights and civil liberties.

On the other hand, to line out government attitudes toward markets, three indicators were chosen: the degree of protection and enforcement of property rights, since Acemoglu and Johnson (2005) showed that the property rights enforcement has a deeper effect in economic growth than contracting institutions; the ease to open and operate a business, which can be considered a measure of the government attitude towards enterprises and the entry barriers imposed to new businesses; and the perception of corruption among the population, as a measure of informal markets in the economy.

4. FACTOR ANALYSIS

Following Adelman and Morris (1965), Temple and Johnson (1998), and Fagerberg and Srholec (2008), this study uses factor analysis to capture the capabilities underneath the indicators, since it can utilise a relatively large number of intercorrelated variables as data inputs and detect a smaller number of factors or variables. The methodology followed for factor analysis is taken from Fagerberg and Srholec (2008).

Table 3: Factor analysis results. Rotated factor matrix.

Indicator	Tech capability	Political system	Market freedom	Financing	Openness	Common
R&D expenditure (% GDP)	0.816	-0.066	-0.055	0.187	-0.231	0.742
Patents (per capita)	0.561	-0.009	0.002	0.168	-0.465	0.588
Science & engineering articles (per capita)	0.900	-0.016	-0.048	0.160	0.028	0.859
ISO 9000 certifications (per capita)	0.476	0.017	-0.049	0.195	0.340	0.413
Mobile and fixed phone lines (per capita)	0.924	0.055	0.003	-0.054	0.010	0.886
Internet users (per 1000 habitants)	0.895	-0.042	-0.097	0.054	-0.034	0.736
Personal computers (per capita)	0.891	-0.021	-0.008	0.157	0.073	0.874
Secondary school enrolment (% gross)	0.755	0.192	0.001	-0.218	0.187	0.786
Tertiary school enrolment (% gross)	0.769	0.042	0.126	-0.312	0.013	0.684
Domestic credit to private sector (% GDP)	0.427	-0.108	0.166	0.610	-0.069	0.797
Market capitalization (% GDP)	-0.075	0.142	0.062	0.912	0.200	0.836
Merchandise imports (% GDP)	-0.025	-0.173	-0.105	0.068	0.782	0.602
FDI inward stock (% GDP)	0.111	0.045	0.114	0.184	0.787	0.714
Property rights	-0.041	0.049	0.936	0.073	0.013	0.913
Easiness to open a business	-0.147	-0.035	0.989	-0.015	0.022	0.873
Corruption	0.210	-0.023	0.811	0.123	-0.038	0.900
Index of democracy	0.179	0.835	0.022	-0.048	-0.027	0.871
Political constraint	0.090	0.778	-0.121	0.211	0.025	0.663
Legislative political competitiveness	-0.167	0.971	-0.037	0.113	-0.111	0.791
Executive political competitiveness	-0.133	0.963	0.021	0.114	-0.026	0.828
Political rights	0.412	0.629	0.075	-0.173	-0.008	0.850
Civil liberties	0.580	0.455	0.061	-0.183	0.070	0.836

Notes: Five factors with eigenvalue>1 were detected, explaining 77.4% of total variance. Extraction method: principal-component factors. Rotation: oblimin oblique. Number of observations = 100 (pooled data for 50 countries in the initial and final period). Source: See Appendix A.

Factor analysis is "the attempt, based on statistical observations, to determine the quantitative relationships between variables where the relationships are due to separate conditioning factors or general causal factors" (Schilderinck, 1970, p. IX). It is based on the assumption that there are a number of general causal factors that give rise to the various relationships between the variables under examination. Unlike all measures analysed by Archibugi and Coco (2005), factor analysis assigns weights to each variable depending on its interaction with all variables considered in the study.

An important consideration to highlight is that the pooled data – formed with the sample of 100 observations obtained from the pooled data for 50 countries in both initial and final periods – was standardised[1], so that changes in a variable over time can be interpreted as changes in both the country's relative position and the indicator's relative importance. Results of factor analysis after rotation are summarised in the matrix of common factor coefficients presented in Table 3.

The extraction method was principal-component factors, in which an orthogonal transformation is made to convert the set of observations of possibly correlated variables into a set of values of principal components. After the extraction, an oblimin oblique rotation was applied to get a clearer pattern. Under this specification, one assumes that factors are correlated, as the theoretical literature relates, and the loadings represent how each of the variables are weighted for each factor.

To determine the number of factors chosen for the analysis, the Kaiser criterion and the scree plot test were used. The Kaiser criterion suggests that only those factors whose eigenvalue is greater than one should be retained, being this value equal to the information that is accounted for by an average single entry. On the other hand, the scree plot graphs each factor on the X-axis against its corresponding eigenvalue on the Y-axis. Since the first factor loading is the one with the highest variance – and, thus, the highest eigenvalue – and the next ones are in decreasing order, the scree plot test states that when the drop ends and the curve forms an elbow shape, the remaining factors after the one starting the elbow should be dropped.

Finally, after these considerations, five factors are retained for this study. Unlike Fagerberg and Srholec (2008), that only retain four factors, the results of the factor analysis in this study got an additional factor that loaded highly on those indicators related to the financing of the private sector, apart from the technological capabilities. A major advantage of this result is that the analysis of the financing sector in economic growth can be done separately, and permits the proper identification of technological capabilities as a factor, unlike Fagerberg and Srholec that label this

[1] A standardized variable is a variable that has been rescaled to have a mean of zero and a standard deviation of one. To do so, first the mean is subtracted from the value for each case, resulting in a mean of zero. Then, the difference

factor as the "innovation system" of the country. And, contrasting the remaining factors with the results of Adelman and Morris (1965) and Temple and Johnson (1998) on social capabilities, a good result of this study is that the different components of social capabilities are not retained in only one factor, so the effects of the components can be analysed separately.

The interpretation of factor loadings may be easier in terms of the squares of the entries in the factor matrix. Each $(a_{ij})^2$ represents the proportion of the total unit variance of variable i explained by factor j. Examining the first row of Table 3, it can be seen that $(0.816)^2$ = 0.6659, $(-0.066)^2$ = 0.00004, $(-0.055)^2$ = 0.00003, $(0.187)^2$ = 0.035, and $(-0.231)^2$ = 0.0533. Then, 66.59% of inter-country variations in R&D expenditure are explained by Factor I, an additional 0.004% by Factor II, only 0.003% by Factor III, 3.5% by Factor IV, and the net contribution of Factor V is 5.33%.

The last column of the table indicates the sum of the squares of the factor loadings for each indicator. This "communality" indicates the proportion of the total unit variance explained by all common factors together, and is analogous to R^2 in regression analysis. The communality of R&D expenditure, for example, is:

$$(0.816)^2+(-0.066)^2+(-0.055)^2+(0.187)^2+(-0.231)^2=0.742$$

That is, 74.2% of inter-country variations in R&D expenditure are associated with the five common factors extracted from the 22 variables considered in this analysis. In addition to indicating the weight of each factor in explaining the observed variables, this factor loadings matrix provides the basis for grouping the variables into common factors. Then, each variable may be assigned to that factor in which it has the highest loading; and, when loadings of a variable in two factors are very close, the variable is assigned to the one with which it might have the closest relationship.

When the variables are assigned to common factors, then a theoretical interpretation of the factors has to be done, by giving a reasonable explanation of the underlying forces that they might represent. Therefore, we shall proceed to identify the factors specified in the results of this analysis.

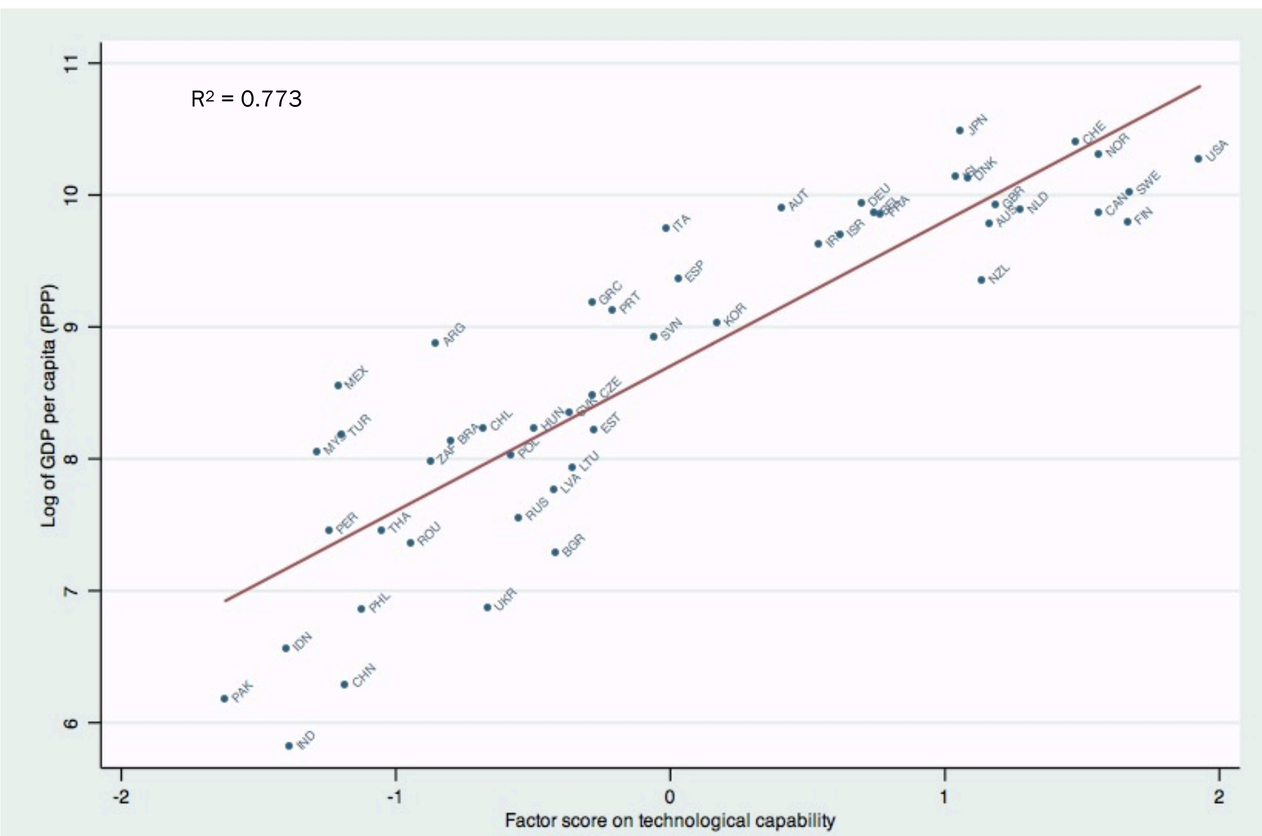
Factor I: Technological capabilities

Indicators that have their highest loadings in Factor I reflect the innovation (R&D expenditure, patents, science and engineering articles), production (ISO 9000 certifications) and diffusion (mobile and fixed phone lines, Internet users, personal computers) of new technologies, as well as the human capital stock (secondary and tertiary school enrolment) of these countries. Then, according to the literature analysed previously, this factor portrays the 'technological capability" (Archibugi & Coco, 2005; Kim, 1997) of countries. Hence, Factor I was labelled as "Technological capability".

Figure 2 shows there is a strong correlation between GDP per capita and the factor scores on technological capability, with deviations from the regression line coming from those countries whose technological capabilities are lower than their GDP per capita levels, most of them emerging market countries.

Factor II: Political system

Figure 2: GDP per capita and technological capabilities (averages over 2002-2004)

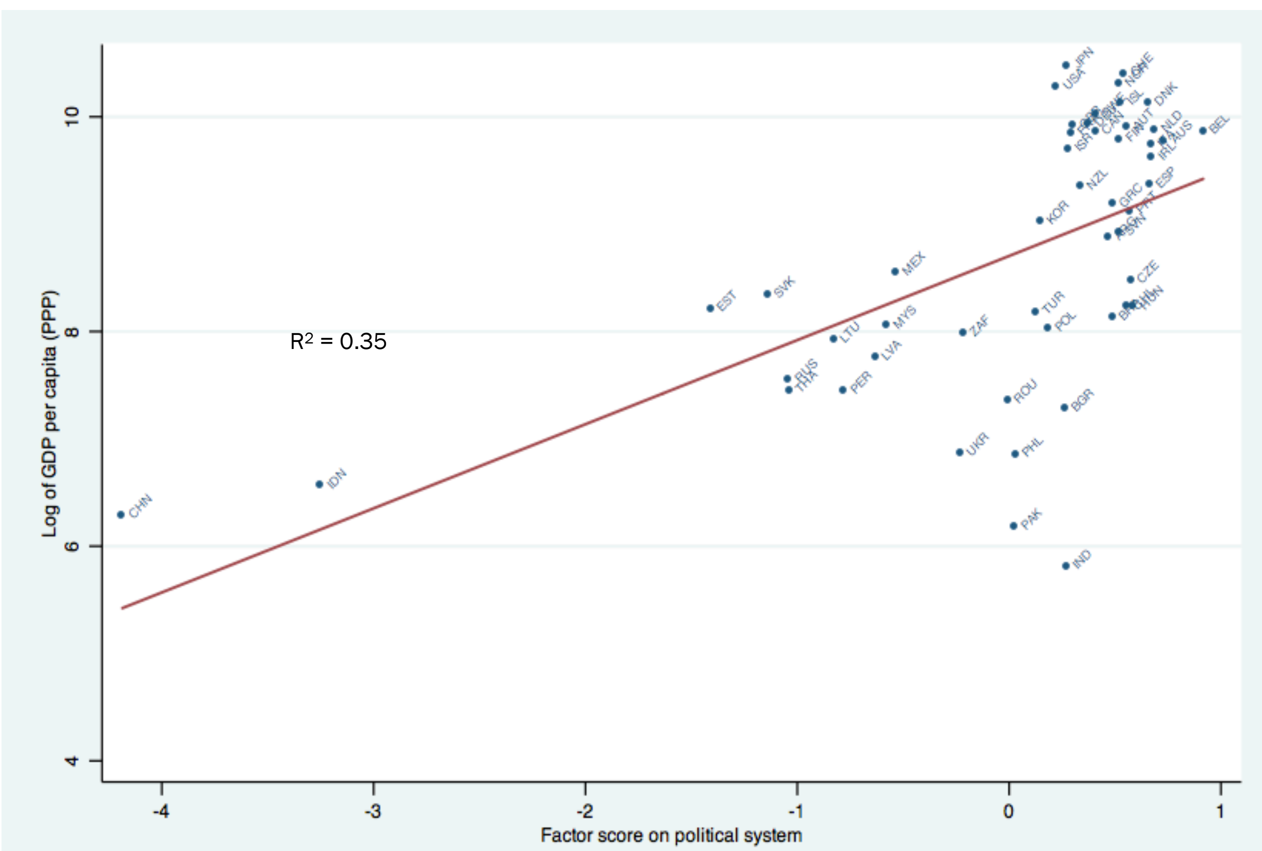


Factor II loads particularly high on indicators that reflect the type of political system: the index of democracy, where the lowest score is for countries ruled by an autocracy; the political constraint for an actor by its own to lead a change in government policy; the competitiveness of elections in both executive and legislative branches of government; and the measures of political rights and civil liberties that citizens of the country are able to exercise. These are all indicators that describe variations among countries in political system. Then, Factor II was labelled "Political system".

As Abramovitz (1986) stated, an important part of social capabilities was the stability of government, which derived in the country's capacity to maintain social and political stability. In particular, the pattern of relations indicated in Factor II is strongly suggestive of broad historical and contemporary differences between the political organisation of the countries of Western Europe and North America and those of the rest of the world.

The main result obtained from Figure 3 is that countries with higher GDP per capita also have higher scores on western democratic political systems, contrary to countries like China, known for

Figure 3: GDP per capita and type of political system (averages over 2002-2004)



its socialist single-party state and lack of civil liberties and political rights. Then, an increase in this factor may be interpreted to represent a movement along a scale that ranges from centralized authoritarian political forms to Western-type systems.

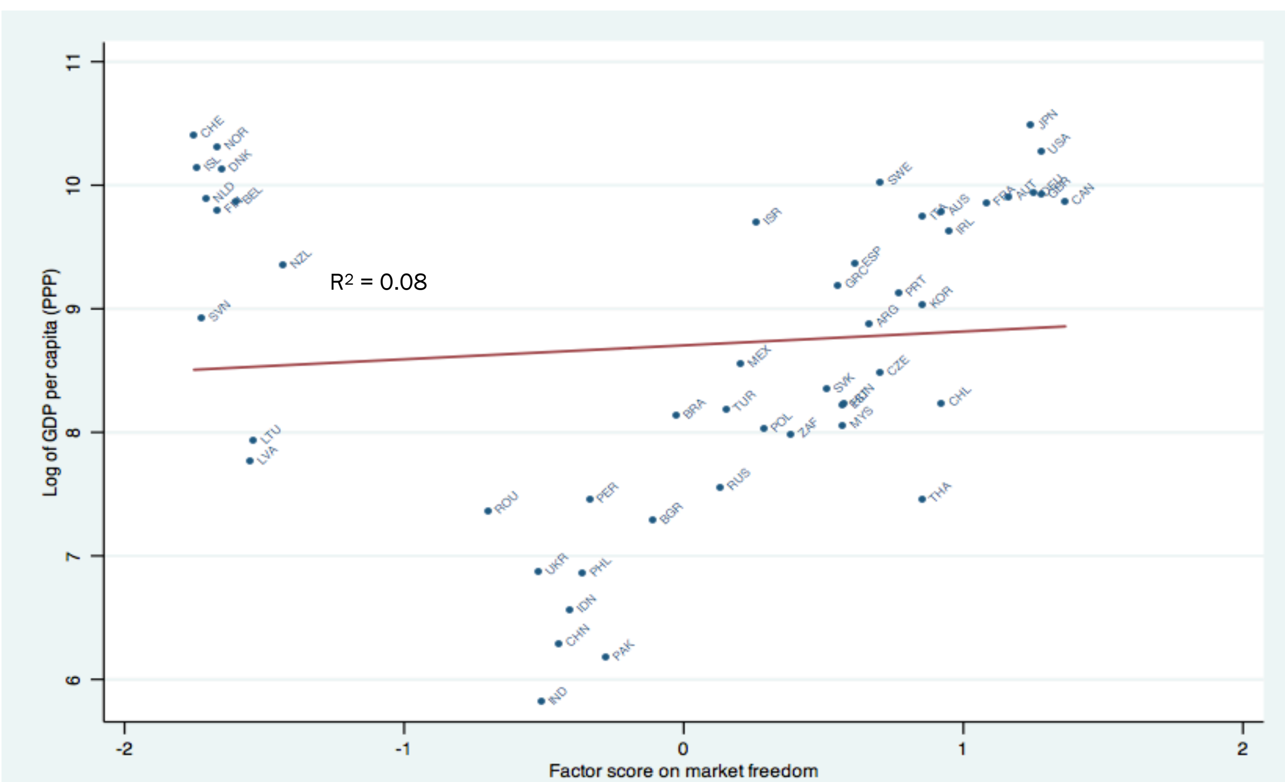
The coefficients resulting from the factor analysis indicate that a typically Western configuration of political traits is generally associated with higher average income. Nevertheless, many emerging countries in Eastern Europe and Southeast Asia are located below the regression line, indicating that although having a western political system, their standards of living do not go accordingly.

Factor III: Market freedom

The third factor loads high on those aspects that reflect the government's attitude towards markets: The degree to which a country's laws protect private property rights and the enforcement of those laws, the degree of regulation in the opening and operation of a business, and the perceptions of people with regard to the extent of corruption. In other words, this factor loads high on indicators reflecting market freedom. Then, Factor III was labelled "Market freedom".

Market freedom also plays an important role in the social capability of a country, since it considers

Figure 4: GDP per capita and market freedom (averages over 2002-2004)

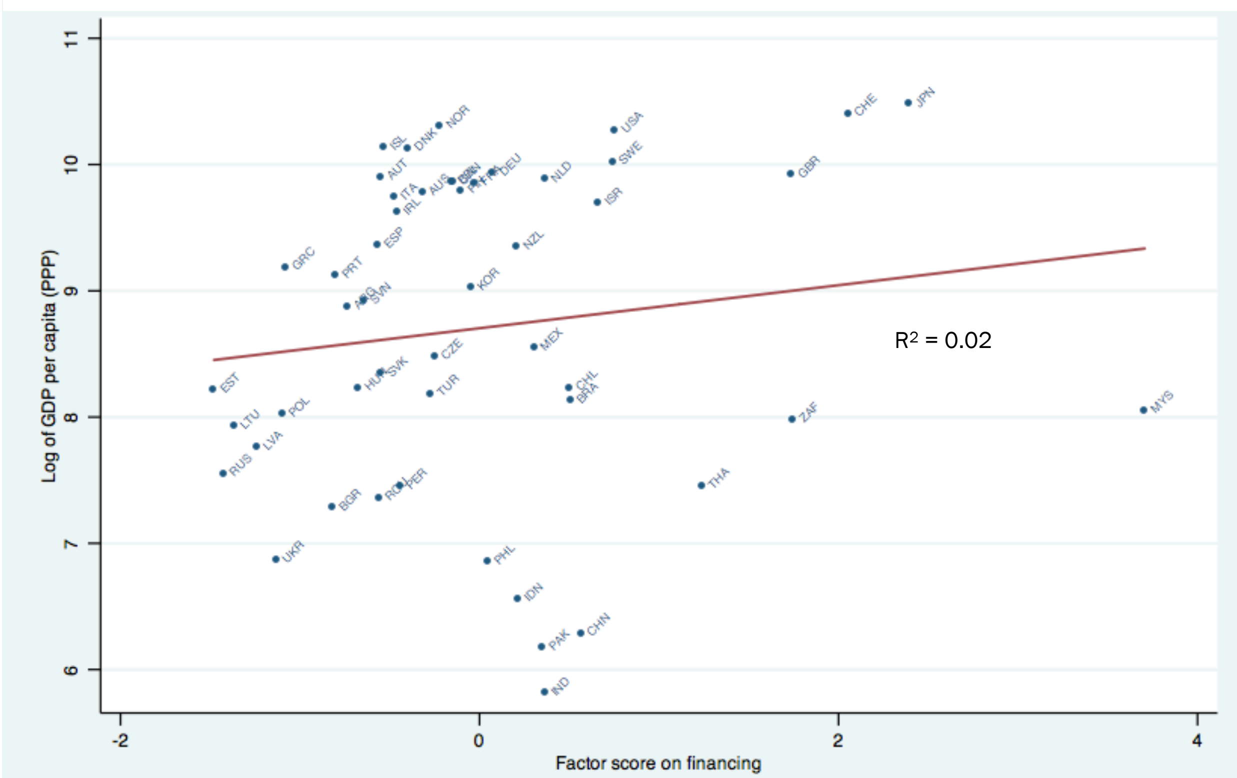


the government's effectiveness in defining and enforcing rules, especially property rights. This also includes intellectual property rights, which is an important factor for new growth theory, since they are essential as entry conditions in the research sector.

This factor can also be considered as a measure of "inclusive institutions" (Acemoglu & Robinson, 2012). Inclusive institutions are designed to create incentives that reward everyone for hard work and innovation. If an entrepreneur assumes the government will not challenge monopolies that unfairly rule out competition, then he won't invest his savings to develop new technology.

Figure 4 shows that the composite variable based on this factor does not correlate with average income. It is important to highlight the relative position of a group of high-income and highly developed countries, such as Switzerland, Denmark, Iceland, Netherlands, Belgium and New Zealand, that got some of the lowest scores on market freedom for this sample

Figure 5: GDP per capita and financing (averages over 2002-2004).



Factor IV: Financing

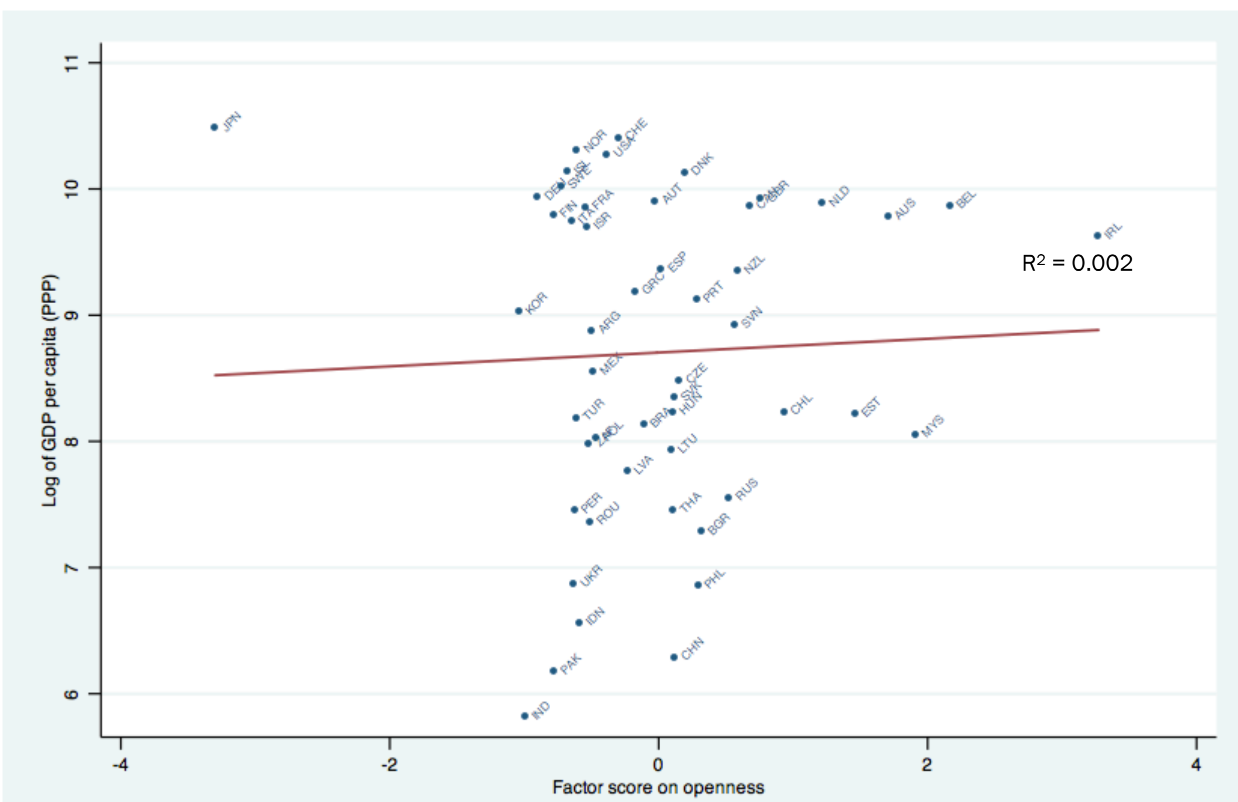
Gerschenkron (1962) highlighted the importance of solid financial institutions and markets for a country's social capability, in order to mobilize capital on a large scale. Factor IV loads highly in only two indicators: domestic credit to private sector and market capitalization of listed companies. Then, this factor can be identified and labelled as "Financing", reflecting the country's capacity to attract, mobilise and utilise financial resources to the private sector.

Examining the factor analysis results from Table 3, an interesting result comes up: indicators of the "financing" factor also load highly on the "technological capability" composite variable, which is consistent with the growth and capabilities theory analysed before, since financing is on the frontier of both technological and social capabilities. Figure 5 shows that the composite variable based on this factor does not correlate with average income.

Factor V: Openness

New growth theory argues that scale effects can be reverted by a country's openness to

Figure 6: GDP per capita and openness to international markets (averages over 2002-2004)



international markets, and that this last consideration is essential for countries to catch-up (Grossman & Helpman, 1991). Factor V loads highly in only two indicators: merchandise imports and inward foreign direct investment; and, since these are considered measures of a country's openness to international trade and capital, Factor V was labelled "Openness".

Despite the theoretical conclusions, the correlation between average income and the factor scores on openness is almost non-existent, as Figure 6 shows; with two developed countries, Japan and Ireland, in both extremes of the openness scale: the first is considered a closed economy, and the latter as a highly economically integrated. It is important to remind that this result comes up even when country size was controlled for both merchandise imports and inward FDI.

5. COMPARISON OF TECHNOLOGICAL CAPABILITIES INDICATORS

Since a possible measure of technological capabilities is obtained from the previous factor analysis, it is important to compare both the statistical approach and the consistency of this measure to other existing technological capabilities in the literature.

To do so, this section follows the methodology developed by Archibugi and Coco (2005) and considers four existing measures of 'technological capabilities', already explained in Section 2.5.3 and compared in Table 1: The WEF Technology Index, developed by the World Economic Forum; the UNDP Technology Achievement Index, reported in the Human Development Report by the United Nations Development Program (UNDP); the ArCo Technological Capabilities Index (ArCo), developed by Archibugi and Coco in their 2004 article "A New Indicator of Technological Capabilities for Developed and Developing Countries (ArCo)"; the Science and Technology Capacity Index (STCI), by the RAND Corporation; along with the measure developed in the previous factor analysis on this study, which will be labelled as "TechCap" from now on.

5.1. COMPONENTS AND STATISTICAL APPROACHES

After analysing the components used to construct each measure, we find several similarities and differences, in terms of the definitions and theoretical considerations made by Kim (1997), Cohen and Levinthal (1990), and Archibugi and Coco (2004, 2005).

First, all four measures use patents as an indicator of a country's 'innovative capacity'; even though patents are a measure of invention, not innovation, this is the best proxy one can find in the existing literature; but, unlike this study's 'TechCap' measure, that is not the case for R&D expenditure and science and engineering articles: R&D expenditure is only considered in the RAND index, while scientific articles are only included in both ArCo and RAND indexes. It is important to highlight that a measure of the 'production capability' (Kim, 1997) is only considered in this study, whereas none of the other measures considered this feature.

Then, in terms of technology diffusion, all four approaches use indicators of information and communication technologies: all four indexes include telephone lines – both mobile and fixed – and Internet users; but only the WEF index includes personal computers. Finally, all indexes incorporate indicators of human capital: WEF and RAND consider only tertiary enrolment, while ArCo includes tertiary enrolment, years of schooling and literacy rate.

By comparing the statistical approaches used to aggregate the three existing measures with the TechCap methodology, we find a central difference: the three indicators of technological capabilities used simple or weighted means of their components to aggregate them, whereas this study weighed the components with factor analysis. Thus, the relative importance of each component relies on the methodology itself, instead of the author's consideration.

5.2. RANKING COMPARISON

Since the diverse methodologies used to construct the indexes do not allow comparisons of absolute values, we can compare the ranking of countries to verify the consistency of results. First, this section compares the position of individual countries and the changes among indexes. To do so, Table 4 examines the rankings provided by the four indexes, with the last two columns showing the rank mean and standard deviation for each country. One can observe that the standard deviation – as a measure of the divergences at the country level – rises in countries placed in the middle of the table.

Table 4: Country ranking by TechCap, WEF, ArCo and RAND for 50 countries.

Country	Tech Cap	WEF	ArCo	RAND	Rank mean	Std dev
United States	1	1	5	1	2.0	2.0
Sweden	2	3	1	5	2.8	1.7
Finland	3	2	2	11	4.5	4.4
Switzerland	6	6	3	8	5.8	2.1
Canada	5	10	6	4	6.3	2.6
Japan	12	4	8	2	6.5	4.4
Norway	4	11	7	15	9.3	4.8
Israel	17	8	4	9	9.5	5.4
Denmark	11	7	9	14	10.3	3.0
UK	8	14	13	6	10.3	3.9
Germany	16	12	12	3	10.8	5.5
Australia	9	16	10	12	11.8	3.1
Netherlands	7	15	11	16	12.3	4.1
South Korea	20	5	18	10	13.3	7.0
Iceland	13	13	14	13	13.3	0.5
France	14	25	19	7	16.3	7.6
New Zealand	10	20	15	23	17.0	5.7
Belgium	15	26	16	19	19.0	5.0
Austria	19	24	17	21	20.3	3.0
Slovenia	23	21	23	22	22.3	1.0
Spain	21	22	22	24	22.3	1.3
Estonia	25	9	28	28	22.5	9.1
Ireland	18	34	20	20	23.0	7.4
Italy	22	38	21	17	24.5	9.3
Czech Rep.	26	18	27	27	24.5	4.4
Slovakia	29	30	25	25	27.3	2.6
Portugal	24	19	31	35	27.3	7.1
Greece	27	27	24	39	29.3	6.7
Hungary	32	29	29	34	31.0	2.4
Russia	33	47	26	18	31.0	12.3
Poland	34	32	30	29	31.3	2.2
Latvia	31	23	33	40	31.8	7.0
Lithuania	28	33	37	30	32.0	3.9
Bulgaria	30	44	32	31	34.3	6.6
Chile	36	28	35	42	35.3	5.7
Brazil	37	31	45	33	36.5	6.2
Ukraine	35	50	36	26	36.8	9.9
Malaysia	47	17	40	47	37.8	14.2
South Africa	39	36	39	37	37.8	1.5
Argentina	38	39	34	41	38.0	2.9
Romania	40	41	38	36	38.8	2.2
Mexico	45	37	41	43	41.5	3.4
Thailand	41	35	44	48	42.0	5.5
China	43	46	47	32	42.0	6.9
Turkey	44	40	42	45	42.8	2.2
Philippines	42	42	46	49	44.8	3.4
India	48	45	49	38	45.0	5.0
Peru	46	43	43	50	45.5	3.3
Indonesia	49	48	48	46	47.8	1.3
Pakistan	50	49	50	44	48.3	2.9

Sources: WEF (2001), Archibugi & Coco (2004), Wagner et al (2004)

High divergence can be better understood when considering the indicators used by each measure, e.g. WEF uses survey data, that doesn't capture structural characteristics, but subjective perceptions. Then, one can expect different results from the other measures. Also, it is visible that countries from Eastern Europe and Southeast Asia have higher standard deviations, meaning possibly that the gathering of technology-related information in those countries is not as accurate as in developed countries. Finally, it is also important to emphasize that all emerging countries are at the bottom of the list. This result, combined with Figure 1, might imply that higher technological capabilities are associated with higher average income. A further examination of this result, using regression analysis, will be made over the next section.

Table 5: Rank correlation matrix among TechCap, WEF, ArCo and RAND indexes for 50 countries[1]

	Tech Cap	WEF	ArCo	RAND
TechCap	1	0.82	0.96	0.90
WEF	0.82	1	0.83	0.71
ArCo	0.96	0.83	1	0.90
RAND	0.90	0.71	0.90	1
Mean	0.89	0.79	0.90	0.84

Sources: WEF (2001), Archibugi & Coco (2004), Wagner et al (2004).
[1] Spearman correlation coefficients.

Now, we can focus on the similarity between rankings, using rank (Spearman) correlation analysis. Table 5 shows the rank correlation matrix among the 50 countries used in this study for the four measures of technological capabilities considered. It becomes evident that the TechCap measure obtained from factor analysis in this study, along with the ArCo index developed by Archibugi and Coco (2004), are the measures that get a higher mean correlation with the other measures. It is important to also emphasize the high rank correlation (0.96) between these two measures, since the ArCo index is the only other indicator that explicitly measures technological capabilities, despite both indicators using different indicators to measure this type of capability.

From Table 4, it is easy to note that divergence grows as one moves to the middle-bottom of the

Table 6: Rank correlation matrix among TechCap, WEF, ArCo and RAND indexes for two sub-samples [1].

First 25 countries (*leaders*)						Last 25 countries (*latecomers*)					
	TechCap	WEF	ArCo	RAND	Mean		TechCap	WEF	ArCo	RAND	Mean
TechCap	1	0.55	0.86	0.63	0.68	TechCap	1	0.50	0.86	0.65	0.67
WEF	0.55	1	0.71	0.61	0.62	WEF	0.50	1	0.49	-0.03	0.32
ArCo	0.86	0.71	1	0.73	0.77	ArCo	0.86	0.49	1	0.56	0.64
RAND	0.63	0.61	0.73	1	0.65	RAND	0.65	-0.03	0.56	1	0.39

Sources: WEF (2001), Archibugi & Coco (2004), Wagner et al (2004).
[1] Spearman correlation coefficients for 2 sub-samples out of the 50 countries considered in this study.

table. To make a further inspection of this result, the 50-countries sample is divided in two sub-samples: the top 25 countries (ordered by rank mean), which will be considered “leaders” on technological capabilities; and the bottom 25 countries, called “latecomers”. Results of this analysis are displayed on Table 6.

A clear result is that “latecomers” have a lower correlation among the different indexes, showing a high polarization of the values among countries in the top and the bottom of the sample. Nevertheless, the highest correlation between indexes is still between TechCap and ArCo (0.86 in both sub-samples), with the former loading higher values with all other indexes than any other indicator, which makes it a consistent measure of technological capabilities.

Then, despite using a different statistical approach, the technological capabilities factor of this study, TechCap, is consistent with other existing measures in the literature.

6. REGRESSION ANALYSIS

An important application of the previous findings in this study is to allow the investigation of the role played by capabilities in economic growth. Following Fagerberg & Srholec's (2008) methodology, the subsequent analysis uses a battery of econometric methods to explore this relationship, using GDP per capita (constant 2000, PPP in US dollars) as a proxy for economic growth.

In addition to the five capabilities previously identified, and following other empirical studies on economic growth in the literature (Acemoglu & Johnson, 2005; Fagerberg & Srholec, 2008; Glaeser, La Porta, Lopez-de-Silanes, & Shleifer, 2004; Rodrik, Subramanian, & Trebbi, 2004; Sachs, 2001), a set of control variables for history, geography and culture are included: longitude and latitude, surface area, access to ocean, land in desert and tropical zones, population density, ethnic and religion fractionalization, malaria fatal risk, oil deposits per capita, number of killed inhabitants in natural disasters and years since national independence. Appendix A gives a brief description of all indicators and their sources.

Table 7: Regression results, levels

Estimation method	OLS							Iteratively reweighted	Stepwise regression
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	8.704***	8.704***	8.704***	8.704***	8.704***	8.704***	8.704***	8.705***	8.704***
	(0.0745)	(0.156)	(0.0997)	(0.164)	(0.180)	(0.0686)	(0.0648)	(0.0684)	(0.0594)
TechCap	1.149***					0.855***	0.838***	0.824***	0.987***
	(0.0752)					(0.142)	(0.185)	(0.142)	(0.094)
Political		0.603***				0.221***	0.161	0.236***	0.173**
		(0.149)				(0.077)	(0.0983)	(0.0772)	(0.068)
Market			1.065***			0.178	0.106	0.179	---
			(0.102)			(0.146)	(0.166)	(0.146)	
Financing				0.526***		0.136	0.238**	0.160*	0.271***
				(0.168)		(0.0813)	(0.103)	(0.0811)	(0.0761)
Openness					0.0485	-0.0813	-0.0445	-0.098	---
					(0.181)	(0.0731)	(0.0911)	(0.0729)	
Geography, history & nature	No	No	No	No	No	No	Yes	No	Yes
Observations	50	50	50	50	50	50	50	50	50
R^2	0.829	0.254	0.695	0.17	0.002	0.868	0.914	0.866	0.903

Dependent variable: Log of average GDP per capita over 2002-2004 (PPP, constant 2000 USD). Beta coefficients reported. Independent variables of capabilities are their lagged levels from the 1992-1994 period. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Also, two considerations are specified: to avoid a possible simultaneity bias, this section uses data for capabilities from the initial period (1992-1994), and the log of GDP per capita for the final period (2002-2004); besides, to elude the problem of comparison between coefficients due to differences in units of measure, beta coefficients are reported.

Results from the regression analysis are displayed in Table 7. Columns 1-5 show that the lagged values of the composite factors for technological capabilities, political system, market freedom and financing have a positive and significant individual effect on economic growth, unlike the openness factor, whose effect is positive but not significant. When the joint effect of the factors is analysed, as shown in Column 6, only two composite variables remain significant: technological capabilities and the political system. An interesting result is that, although its effect is not significant, the openness factor has a negative effect on economic growth, contrary to the theoretical considerations of openness in the literature.

Adding the set of control variables for geography, history and nature, develops three new results, as shown in Column 7. First, the coefficient of the technological capabilities factor is vaguely smaller but still significant, which implies that geography, history and nature may have an effect on the capacity to develop technological capabilities of a country. Second, the significance of the political system factor does not hold, meaning that the differences in the exogenous variables may influence the importance of the political system in economic growth; and third, the financing factor has a positive and significant effect, possibly implying that a well developed financing system may help a country offset the effects of the considered exogenous variables in economic growth.

Finally, two robustness tests are included: iteratively reweighted least squares and a stepwise regression. The iteratively reweighted least squares technique is an alternative to the least squares regression that can be used to detect and remove outliers or influential observations, giving lower weights to outliers. On the other hand, the stepwise regression adds and removes variables based only on the t-statistics of their estimated coefficients, finally eliminating those variables that do not contribute to the explanatory power of the model. As Fagerberg and Srholec (2008), the boundary for removal in this technique was set at a 20% and the level to reintroduce a variable is 15%.

Results of these robustness tests are shown in Columns 8 and 9. In both tests, the coefficient of technological capabilities remains positive and significant. Besides, the political system and financing factors have a less significant but still positive effect on economic growth; and the market freedom and openness factors are removed from the model in the stepwise regression, meaning they do not contribute to the explanatory power of the model. The removal of these two factors increases the coefficient of the technological capabilities factor, and the significance and effect of the financing factor. Then, a conclusion of the first regression analysis – using only levels of current and lagged values – is that the only robust result is the positive and significant effect of the development of technological capabilities on economic growth.

Finally, in an attempt to prove if the implications of the previous analysis could be sustained in a dynamic framework, Fagerberg and Srholec (2008) used the so-called "Barro regressions" (Barro, 1991). Among the advantages of this empirical framework is the consistency with both neoclassical and Schumpeterian perspectives in the inclusion of the log of the initial level of GDP per capita; in the latter, which concerns this study, an initial low GDP per capita indicates the potential of a country to catch-up.

On the other hand, a main disadvantage of the use of Barro regressions in this study is the short period of time considered – due to data availability – implying only possible short-term effects. Barro (1991) designed this empirical framework for a larger time span, in an attempt to analyse long-term implications. Then, results have to be taken carefully, and a wider period of time would be more desirable in future studies, when better statistical tools and sources are available.

Besides the initial income, the inclusion of certain conditional variables can also lead to different conclusions. Then, also following Fagerberg and Srholec (2008), initial levels will be included in some specifications, since a higher level of a certain feature may induce higher growth indefinitely. Table 8 presents the results of the Barro regressions. As expected, the log of initial GDP per capita has a negative and significant effect on economic growth in all specifications, displaying the potential of a country to catch-up. Nevertheless, the other results of this analysis do not go along with what was expected from the theoretical considerations, from results in Table 7 and the results obtained by Fagerberg and Srholec (2008).

From the basic Barro regression model, displayed in Columns 1-2, one can observe that the change in technological capabilities has a significant effect on subsequent economic growth, but that this effect is negative; this means that an increase in a country's technological capabilities factor is negative for economic growth. When the exogenous variables accounting for geography, history and nature are included, the negative effect of changes in technological capabilities exacerbates, and the change in the political system factor has now a significant but negative effect: as a country adopts more Western-type political institutions, its economic growth is affected in a negative manner. Finally, the only significant and positive effect comes from the change in the openness factor, implying that positive changes in the openness of a country to international markets have a direct effect in economic growth.

When the model is expanded to include the initial levels of the five dimensions of capabilities, results from the basic model are not considerably altered – although now the changes in the

Table 8: Regression results, growth

Estimation method	**Basic model**		**Initial levels**		**Iteratively reweighted**	**Stepwise regression**	**Stepwise, only OECD**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	6.535***	9.014***	10.68***	13.37***	13.15***	10.90***	26.94***
	(1.813)	(2.571)	(3.440)	(4.200)	(2.937)	(2.436)	(3.779)
Log initial GDP per capita	-0.477**	-0.762**	-0.954**	-1.263**	-1.250***	-0.979***	-2.681***
	(0.207)	(0.295)	(0.395)	(0.483)	(0.338)	(0.280)	(0.415)
TechCap			0.645	0.566	0.658	---	2.057***
			(0.567)	(0.695)	(0.487)		(0.501)
Political			-0.977***	-0.996***	0.229	-0.939***	---
			(0.282)	(0.312)	(0.381)	(0.242)	
Market			1.212**	1.283**	0.939**	1.313***	---
			(0.463)	(0.483)	(0.395)	(0.326)	
Financing			-0.0442	0.0982	0.0270	---	---
			(0.219)	(0.302)	(0.187)		
Openness			0.270	0.362	0.0726	0.291	---
			(0.201)	(0.236)	(0.173)	(0.180)	
Δ TechCap	-1.912**	-2.100*	-1.540**	-1.143	-1.050*	-1.136*	1.707***
	(0.750)	(1.086)	(0.643)	(0.878)	(0.554)	(0.619)	(0.566)
Δ Political	-0.188	-0.708*	-0.740***	-0.941**	-0.165	-0.920***	---
	(0.237)	(0.407)	(0.252)	(0.356)	(0.250)	(0.228)	
Δ Market	-0.209	-0.280	0.183	0.164	0.178	---	0.176
	(0.182)	(0.219)	(0.183)	(0.202)	(0.157)		(0.110)
Δ Financing	-0.0908	0.557	0.372	0.442	0.253	0.468	-0.585**
	(0.383)	(0.557)	(0.331)	(0.485)	(0.282)	(0.299)	(0.265)
Δ Openness	1.044***	1.675***	0.577	1.030**	0.375	0.954***	1.010***
	(0.383)	(0.496)	(0.386)	(0.455)	(0.331)	(0.349)	(0.201)
Geography, history & nature	No	Yes	No	Yes	No	Yes	Yes
Observations	50	50	50	50	50	50	33
R^2	0.829	0.254	0.695	0.170	0.866	0.903	0.832

Dependent variable: Annual growth of GDP per capita over 1992-2004 (PPP, constant 2000 USD). Beta coefficients reported. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

openness factor are not significant – and only two initial levels have a significant effect in economic performance: the political system factor, with a negative effect in the economic growth of the time of period studies; and the market freedom factor, with a less significant but positive effect in GDP growth. Finally, robustness tests show that coefficients are not robust and that this methodology displays many considerations.

However, when a stepwise regression is used, but only considering developed countries – those that belong to the OECD – results change considerably. First, the only significant initial level is the one from the technological capabilities factor, which now has a positive effect on economic growth. This result is consistent with new growth theory, where a higher initial level of technological capabilities may induce higher growth indefinitely (Fagerberg & Srholec, 2008). Also, the changes in this factor load significant and positive, implying that changes in technological capabilities have a positive effect on economic growth, but only in developed countries. Finally, both the changes in the private financing system and the openness factors load significant, but with negative and positive effects, respectively.

This variation in the results after the exclusion of the emerging market countries can have many interpretations. From a statistical viewpoint, a possible explanation is the possibility of an endogeneity bias that can alter the coefficients[2]. Nonetheless, the Durbin-Wu-Hausman procedure failed to identify the possibility of an endogeneity bias. Another possible cause is the existence of measurement errors in the indicators reported by developing countries that might bias the results, especially the reliability of indicators related to science, innovation and ICT. A third statistical reason is the length of the time span considered for this analysis, making Barro regressions not appropriate for this methodology. Finally, the number of observations used in this study can explain the change in results.

New growth theory also offers a possible explanation for this outcome. Emerging countries are still imitating foreign technologies, as their rankings on the technological capabilities indicators show, so a plausible explanation might be that investing in technological capabilities reduces their income without positive returns from this investment; unlike developed countries, where investment in technological capabilities increases the average per capita income. Acemoglu,

[2] For example, since R&D expenditure is included in the technological capabilities variable, it would be natural if this were an endogenous variable.

Aghion and Zilibotti (2006) constructed a simple endogenous model based on the idea that the optimal innovation strategy for catching up depends on the country's distance to the world technology frontier: as an economy approaches the world technology frontier, innovation gains relative importance vis-à-vis imitation as a source of productivity growth.

In this way, developing countries, that are relatively backward economies who have not developed a proper innovation system and the needed technological and social capabilities, will follow an investment-based strategy, which is characterised by mature and big firms and large investments, long-term relationships but little selection. As these countries move closer to the world technology frontier, the adoption of established technologies becomes more difficult, so industries and firms shift to an innovation-based strategy, characterised by younger firms, short-term relationships and less investment, but a better selection of entrepreneurs.

In this theoretical context, it is easier to understand why an increase in the development of technological capabilities might have a negative impact on economic growth: promoting an innovation-based strategy is not optimal when a country's distance to technology frontier is relatively large, compared to developed countries. Then, an improvement or increase of certain features of the technological capability factor might help the transformation and diffusion of existing information into some innovation or technological improvement, like information and communication technologies, science and engineering articles or patents; unlike other features, like R&D expenditure, whose increase might not have a positive effect in the technological environment, but a negative implication for economic growth.

This result opens a path for future research – especially in terms of public policy – based on the work of Acemoglu, Aghion and Zilibotti (2006), and Basu and Weil (1998): what will the optimal technological strategy be for emerging countries in the future years of transition, when the technology gap with developed countries closes even more?

7. CONCLUSIONS

Adequate indicators of social and technological capabilities are increasingly needed to understand why do countries imitate or innovate, and why national economic performances differ. This study attempted to incorporate existing indicators of several features of the technological and social characteristics of countries and develop composite variables of capabilities through factor analysis. A noteworthy result is that, in spite of using a different statistical approach, the composite variable for technological capabilities found in this work is consistent with other existing measures in the literature.

The central finding of this study is that the development of technological capabilities is highly correlated with subsequent economic growth, which goes accordingly to the findings of the new growth theory. Nevertheless, the returns of the improvement of technological capabilities on economic growth will depend inversely on the distance to the world technology frontier. Therefore, this study supports empirically the results of Aghion and Zilibotti (2006) about the relation between the optimal innovation strategy for catching up and the distance to the world technology frontier.

Future research should make the most of new data to gain a better understanding from the empirical study of the complex relationship between social and technological capabilities, and economic performance. Besides, an appropriate measure of imitation and innovation would give us a better insight on what should the proper policy be to take advantage of the development of capabilities, in order to boost sustained economic growth.

8. APPENDICES

8.1. APPENDIX A: INDICATORS, DATA AND SOURCES

Table 9: Indicators, scales, estimated data and sources

Indicator and definition	Scale	Estimated (%)	Source
Gross Domestic Product (PPP, constant 2000 USD)	Per capita	0	World Bank (World Development Indicators)
USPTO patents: Number of utility patents by the U.S. Patent and Trademark Office (USPTO).	Per capita	0	USPTO
Science and engineering articles: Number of articles published in journals classified and covered by Science Citation Index (SCI) and Social Sciences Citation Index (SSCI).	Per capita	0	U.S. National Science Foundation
ISO 9000 certifications: Standards that define a quality management and quality assurance program.	Per capita	1	International Organization for Standardization (ISO Surveys of ISO 9000 Certificates)
Fixed line and mobile phone subscribers: Users of telephone mainlines and portable telephones subscribed to a public telephone service.	Per capita	0	World Bank (World Development Indicators)
Internet users: People with access to the worldwide network.	Per 1000 inhabitants	0	World Bank (World Development Indicators)
Personal computers: Computers designed to be used by a single individual.	Per 1000 inhabitants	0	World Bank (World Development Indicators)
Secondary school enrolment: Ratio of the number of secondary students of all ages (gross) as a percentage of the secondary school-age population	% Gross	5	World Bank (World Development Indicators), UNESCO Institute for Statistics
Tertiary school enrolment: Ratio of the number of tertiary students of all ages (gross) as a percentage of the tertiary school-age population	% Gross	6	World Bank (World Development Indicators), UNESCO Institute for Statistics
Domestic credit to private sector: Financial resources provided to the private sector such as through loans, purchases of non-equity securities, and trade credits and other accounts receivable	% of GDP	0	World Bank (World Development Indicators)
Market capitalization of listed companies: Market value of domestically incorporated companies listed on the country's stock exchanges at the end of the year	% of GDP	0	World Bank (World Development Indicators)
Merchandise imports: CIF value of goods received from the rest of the world.	% of GDP	0	World Bank (World Development Indicators)
Foreign direct investment inward stock: Net inflows of investment to acquire a lasting management interest in an enterprise operating in an economy other than that of the investor.	% of GDP	0	UNCTAD
Index of democracy and autocracy: The degree of democracy versus autocracy (POLITY2 variable in increasing order from autocracy to democracy)	Index, -10 – 10	0	Marshall and Jaggers (2003)
Political constraint: The extent to which a change in the preferences of any one actor may lead to a change in government policy (POLCONIII variable)	Index, 0–1	0	Henisz (2010)
Legislative index of political competitiveness: Competitiveness of elections into legislative branches (LIEC variable)	Index, 1–7	0	World Bank's Database of Political Institutions, 2012
Executive index of political competitiveness: Competitiveness for post in executive branches in government (EIEC variable)	Index, 1–7	0	World Bank's Database of Political Institutions, 2012
Political rights: The degree to which people participate freely in the political process derived from standards by the Universal Declaration of Human Rights. The scale of the indicator has been reversed into increasing order, while keeping its original range	Index, 1–7	0	Freedom House (Index of Freedom in theWorld, various issues)

Indicator and definition	Scale	Estimated (%)	Source
Civil liberties: The degree of the freedoms of expression and belief, associational and organizational rights, rule of law, and personal autonomy without interference from the state derived from standards by the Universal Declaration of Human Rights. The scale of the indicator has been reversed into increasing order, while keeping its original range.	Index, 1–7	0	Freedom House (Index of Freedom in theWorld, various issues)
Property rights: The degree to which a country's laws protect private property rights and the degree to which its government enforces those laws. The scale of the indicator has been reversed into increasing order, while keeping its original range	Index, 0–5	0	Heritage Foundation (Index of Economic Freedom)
Easiness to open a business: How easy or difficult it is to open and operate a business. The scale of the indicator has been reversed into increasing order, while keeping its original range	Index, 0–5	0	Heritage Foundation (Index of Economic Freedom)
Informal market: The perceptions of people with regard to the extent of corruption, defined as the misuse of public power for private benefit. The scale of the indicator has been reversed into increasing order, while keeping its original range	Index, 0–5	0	Heritage Foundation (Index of Economic Freedom)
Longitude of country centroid: Longitude is measured from the Prime Meridian with positive values going east and negative values going west. Absolute values were taken	Degrees	0	Gallup et al (1999), CID Geography Datasets
Latitude of country centroid: Latitude is measured from the equator, with positive values going north and negative values going south. Absolute values were taken	Degrees	0	Gallup et al (1999), CID Geography Datasets
Surface area: Country's total area, including areas under inland bodies of water and some coastal waterways	Log of km^2	0	Gallup et al (1999), CID Geography Datasets
Access to ocean: Proportion of land within 100 km of the ocean coastline, excluding coastline in arctic and sub-arctic region above the winter extent of sea ice	%	0	Gallup et al (1999), CID Geography Datasets
Land in desert ecozone: Proportion of land in (temperate or tropical) desert ecozone	%	0	Gallup et al (1999), CID Geography Datasets
Land in tropical ecozone: Proportion of land in tropical ecozone	%	0	Gallup et al. (1999)-CID Geography Datasets
Population density: Midyear population divided by land area	Log people per km^2	0	World Bank (World Development Indicators 2006)
Malaria fatal risk: Proportion of population at risk of contracting falciparum malaria	%	0	Earth Institute (Jeffrey D. Sachs Malaria Dataset)
Ethnic fractionalization: The probability that two randomly selected people from a given country will not belong to the same ethic group	Index, 0–1	0	Alesina et al. (2003)
Religion fractionalization: The probability that two randomly selected people from a given country will not belong to the same religion	Index, 0–1	0	Alesina et al. (2003)
Oil deposits: Proven crude oil reserves in billion barrels (bbl)	Log of (bbl + 1) per capita	0	The CIA World Factbook 2005
Killed in natural disasters: Number of persons killed (confirmed as dead, missing and presumed dead) in disasters of natural origin (droughts, earthquakes, extreme temperatures, floods, slides, waves, wind storms, etc.)	Log of killed per capita	0	UNEP (The GEO Data Portal)—based on the OFDA/CRED International Disaster Database 2004
National independence: Number of years since gaining national independence over the period 1816–2004 (maximum truncated at 188 years)	Log of years	0	Fearon (2003); missing data filled from the CIA World Factbook

8.2. APPENDIX B: FACTOR SCORES BY COUNTRY

Table 10: Factor scores by country, periods 1992-1994 and 2002-2004

		Technological capability		Political system		Free market	
Country	WB Code	1992-1994	2002-2004	1992-1994	2002-2004	1992-1994	2002-2004
OECD members							
Australia	AUS	1.35	1.16	0.46	0.73	1.28	0.92
Austria	AUT	0.65	0.40	0.35	0.55	0.60	1.16
Belgium	BEL	0.78	0.74	0.80	0.92	0.45	-1.60
Canada	CAN	0.96	1.56	0.12	0.41	1.37	1.36
Czech Republic	CZE	-0.02	-0.28	0.31	0.57	-0.19	0.70
Denmark	DNK	1.37	1.08	0.29	0.66	1.86	-1.65
Finland	FIN	1.34	1.67	0.40	0.52	1.44	-1.67
France	FRA	0.46	0.77	0.38	0.29	0.22	1.08
Germany	DEU	0.77	0.70	0.19	0.37	0.60	1.25
Greece	GRC	-0.16	-0.28	0.26	0.49	-0.23	0.55
Iceland	ISL	1.31	1.04	0.20	0.53	1.39	-1.74
Ireland	IRL	0.46	0.54	0.44	0.67	1.37	0.95
Israel	ISR	0.91	0.62	0.24	0.28	0.06	0.26
Italy	ITA	0.37	-0.01	0.24	0.67	0.07	0.86
Japan	JPN	0.96	1.06	0.26	0.27	0.14	1.24
Netherlands	NLD	1.07	1.28	0.55	0.69	0.75	-1.71
New Zealand	NZL	1.02	1.14	0.34	0.34	1.52	-1.43
Norway	NOR	1.17	1.56	0.41	0.52	0.79	-1.67
Portugal	PRT	0.03	-0.21	0.34	0.57	0.35	0.77
Slovakia	SVK	-0.31	-0.37	0.44	-1.14	-0.58	0.51
Slovenia	SVN	0.36	-0.06	0.47	0.52	0.27	-1.72
South Korea	KOR	0.92	0.17	-0.18	0.15	-0.02	0.86
Spain	ESP	0.38	0.03	0.52	0.66	0.34	0.61
Sweden	SWE	1.77	1.67	0.30	0.41	0.80	0.71
Switzerland	CHE	1.35	1.48	0.42	0.54	0.49	-1.75
United Kingdom	GBR	0.90	1.19	0.13	0.30	1.38	1.28
United States	USA	1.14	1.93	0.05	0.22	1.30	1.28
Emerging countries							
Argentina	ARG	-0.87	-0.85	0.23	0.47	-0.67	0.66
Brazil	BRA	-0.96	-0.80	0.17	0.49	-0.52	-0.02
Bulgaria	BGR	-0.71	-0.42	0.30	0.26	-1.13	-0.11
China	CHN	-1.14	-1.18	-5.32	-4.19	-1.47	-0.44
India	IND	-1.65	-1.38	0.05	0.27	-1.24	-0.51
Indonesia	IDN	-1.68	-1.40	-0.40	-3.25	-1.75	-0.41
Latvia	LVA	-0.37	-0.42	0.39	-0.63	-0.45	-1.55
Lithuania	LTU	-0.34	-0.35	0.50	-0.83	-0.34	-1.54
Malaysia	MYS	-1.08	-1.29	-0.75	-0.58	-0.68	0.57
Pakistan	PAK	-1.83	-1.62	-4.35	0.03	-1.27	-0.28
Peru	PER	-1.22	-1.24	0.33	-0.78	-1.31	-0.34
Philippines	PHL	-1.31	-1.12	-0.10	0.03	-1.30	-0.36
Romania	ROU	-0.96	-0.94	0.25	-0.01	-1.54	-0.70
Russia	RUS	-0.98	-0.55	-1.07	-1.04	-1.54	0.13
South Africa	ZAF	-1.04	-0.87	0.36	-0.22	-0.35	0.39
Thailand	THA	-1.20	-1.05	0.02	-1.04	-0.34	0.85
Ukraine	UKR	-0.88	-0.66	-0.54	-0.23	-1.60	-0.52
OECD and emerging countries							
Chile	CHL	-0.60	-0.68	0.31	0.55	0.97	0.92
Estonia	EST	0.12	-0.28	0.39	-1.41	0.61	0.57
Hungary	HUN	-0.03	-0.49	0.33	0.59	0.04	0.57
Mexico	MEX	-1.11	-1.21	-0.05	-0.53	-0.67	0.21
Poland	POL	-0.37	-0.58	0.49	0.19	-0.12	0.29
Turkey	TUR	-1.10	-1.20	-0.25	0.13	-1.15	0.15

Country	WB Code	Financing 1992-1994	Financing 2002-2004	Openness 1992-1994	Openness 2002-2004
OECD members					
Australia	AUS	0.58	-0.32	0.78	1.71
Austria	AUT	-0.11	-0.55	-0.17	-0.02
Belgium	BEL	-0.25	-0.16	3.03	2.17
Canada	CAN	1.24	-0.15	0.11	0.68
Czech Republic	CZE	-0.84	-0.25	1.14	0.16
Denmark	DNK	0.24	-0.40	-0.06	0.19
Finland	FIN	0.14	-0.10	-0.32	-0.78
France	FRA	0.16	-0.03	-0.25	-0.54
Germany	DEU	0.16	0.08	-0.93	-0.90
Greece	GRC	-0.87	-1.08	-0.54	-0.17
Iceland	ISL	1.01	-0.53	-1.11	-0.68
Ireland	IRL	0.08	-0.46	2.07	3.27
Israel	ISR	0.74	0.66	-0.73	-0.53
Italy	ITA	-0.49	-0.47	-0.07	-0.65
Japan	JPN	1.71	2.39	-2.96	-3.30
Netherlands	NLD	1.03	0.36	1.58	1.22
New Zealand	NZL	-0.10	0.21	-0.30	0.59
Norway	NOR	-0.29	-0.22	-0.92	-0.60
Portugal	PRT	-0.39	-0.80	0.06	0.28
Slovakia	SVK	-0.93	-0.55	0.71	0.12
Slovenia	SVN	-1.11	-0.64	0.49	0.57
South Korea	KOR	0.17	-0.05	-1.72	-1.04
Spain	ESP	0.15	-0.56	0.34	0.02
Sweden	SWE	0.52	0.74	0.08	-0.72
Switzerland	CHE	3.21	2.05	0.61	-0.30
United Kingdom	GBR	1.11	1.74	-0.36	0.76
United States	USA	1.45	0.76	-0.73	-0.38
Emerging countries					
Argentina	ARG	-0.73	-0.73	-0.25	-0.50
Brazil	BRA	-0.43	0.51	-0.21	-0.11
Bulgaria	BGR	-1.18	-0.82	0.52	0.32
China	CHN	0.62	0.57	-0.27	0.12
India	IND	0.09	0.36	-1.27	-0.99
Indonesia	IDN	-0.22	0.22	-1.07	-0.59
Latvia	LVA	-1.38	-1.24	0.44	-0.23
Lithuania	LTU	-1.47	-1.37	0.61	0.10
Malaysia	MYS	2.18	3.71	0.95	1.91
Pakistan	PAK	-0.12	0.35	-1.37	-0.78
Peru	PER	-0.65	-0.44	-0.76	-0.62
Philippines	PHL	-0.57	0.05	0.00	0.29
Romania	ROU	-1.00	-0.56	0.01	-0.51
Russia	RUS	-0.40	-1.43	0.34	0.53
South Africa	ZAF	1.86	1.75	-0.38	-0.52
Thailand	THA	0.34	1.24	0.30	0.11
Ukraine	UKR	-1.02	-1.13	0.05	-0.63
OECD and emerging countries					
Chile	CHL	0.27	0.50	0.35	0.94
Estonia	EST	-0.71	-1.48	1.94	1.46
Hungary	HUN	-0.90	-0.67	1.46	0.11
Mexico	MEX	-0.91	0.30	-0.41	-0.48
Poland	POL	-1.39	-1.10	-0.01	-0.46
Turkey	TUR	-0.63	-0.27	-0.80	-0.61

9. REFERENCES

Abramovitz, M. (1986). Catching up, forging ahead, and falling behind. *Journal of Economic History, 46*(2), 385-406.

Abramovitz, M. (1994). The origins of the postwar catch-up and convergence boom. In J. Fagerberg, B. Verspagen & N. von Tunzelmann (Eds.), *The dynamics of technology, trade and growth* (pp. 21-52). Aldershot, UK: Edward Elgar.

Abramovitz, M., & David, P. A. (1973). Reinterpreting economic growth: Parables and realities. *The American Economic Review, 63*(2), 428-439.

Abramovitz, M. (1956). Resource and output trends in the United States since 1870. *The American Economic Review, 46*(2), 5-23.

Acemoglu, D. (2008). *Introduction to Modern Economic Growth*. Princeton, NJ: Princeton University Press.

Acemoglu, D., Aghion, P., & Zilibotti, F. (2006). Distance to frontier, selection, and economic growth. *Journal of the European Economic Association, 4*(1), 37-74.

Acemoglu, D., & Johnson, S. (2005). Unbundling institutions. *Journal of Political Economy, 113*(5), 949-995.

Acemoglu, D., & Robinson, J. (2012). *Why Nations Fail: The origins of power, prosperity, and poverty*. New York, NY: Crown Business.

Adelman, I., & Morris, C. T. (1965). A factor analysis of the interrelationship between social and political variables and per capita gross national product. *The Quarterly Journal of Economics, 79*(4), 555-578.

Aghion, P., & Howitt, P. (1992). A model of growth through creative destruction. *Econometrica, 60*(2), 323-351.

Alesina, A., Devleeschauwer, A., Easterly, W., Kurlat, S., & Wacziarg, R. (2003). Fractionalization. *Journal of Economic Growth, 8*(1), 155-194. Retrieved from http://www.anderson.ucla.edu/faculty_pages/romain.wacziarg/downloads/fractionalization.xls

Archibugi, D., & Coco, A. (2004). A new indicator of technological capabilities for developed and developing countries (ArCo). *World Development, 32*(4), 629-654. doi:10.1016/j.worlddev.2003.10.008

Archibugi, D., & Coco, A. (2005). Measuring technological capabilities at the country level: A survey and a menu for choice. *Research Policy, 34*(2), 175-194.

Barro, R. J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics*, 106(2), 407-443.

Basu, S., & Weil, D. N. (1998). Appropriate technology and growth. *The Quarterly Journal of Economics*, 113(4), 1025-1054.

Baumol, W. J. (1986). Productivity growth, convergence, and welfare: What the long-run data show. *The American Economic Review, 76*(2), 1072-1085.

Baumol, W. J., Blackman, S. A. B., & Wolff, E. N. (1989). *Productivity and American leadership: The long view*. Cambridge, MA: MIT Press.

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D. *The Economic Journal, 99*(397), 569-596.

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on learning and innovation. *Administrative Science Quarterly, 35*(1), 128-152.

Denison, E. F. (1967). *Why growth rates differ: Postwar experience in nine western countries*. Washington, DC: Brookings Institution.

Edquist, C. (2004). Systems of innovation: Perspectives and challenges. In J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 181-208). Oxford: Oxford University Press.

Fagerberg, J. (1994). Technology and international differences in growth rates. *Journal of Economic Literature, 32*(3), 1147-1175.

Fagerberg, J. (2006). Innovation, technology and the global knowledge economy: Challenges for future growth. Paper presented at the *"Green Roads to Growth" Project and Conference,* Copenhagen.

Fagerberg, J., & Godinho, M. M. (2005). Innovation and catching-up. In J. Fagerberg, D. C. Mowery & R. R. Nelson (Eds.), *The Oxford Handbook of Innovation* (pp. 514-543). New York, NY: Oxford University Press.

Fagerberg, J., & Srholec, M. (2008). National innovation systems, capabilities and economic development. *Research Policy, 37*(9), 1417-1435. doi:10.1016/j.respol.2008.06.003

Freedom in the world (2013). Washington, DC: Freedom House.

Freeman, C. (1987). *Technology policy and economic performance: Lessons from Japan*. London: Pinter.

Gallup, J. L., Sachs, J. D., & Mellinger, A. D. (2007). *Geography datasets*. Cambridge, MA: Center for International Development, Harvard University. Retrieved from http://www.cid.harvard.edu/ciddata/geographydata.htm

Gerschenkron, A. (1962). Economic backwardness in historical perspective. In A. Gerschenkron (Ed.), *Economic backwardness in historical perspective, a book of essays* (1st ed., pp. 5-30). Cambridge, MA: Belknap Press.

Glaeser, E. L., La Porta, R., Lopez-de-Silanes, F., & Shleifer, A. (2004). Do institutions cause growth? *Journal of Economic Growth, 9*(3), 271-303.

The great innovation debate. (2013). *The Economist, 406*(8818), 11.

Grossman, G. M., & Helpman, E. (1991). *Innovation and growth in the global economy*. Cambridge, MA: MIT Press.

Gwartney, J., Lawson, R., & Hall, J. (2006). *Economic freedom of the world: 2006 annual report.* The Fraser Institute. Retrieved from www.freetheworld.com.

Has the ideas machine broken down? Innovation pessimism. (2013). *The Economist, 406*(8818), 21-28.

Henisz, W. (2010). *POLCON Database 2005*. Philadelphia, PA: Wharton School of the University of Pennsylvania. Retrieved from http://www-management.wharton.upenn.edu/henisz/

IMF. Emerging markets. Retrieved February 12, 2013, from http://www.imf.org/external/np/exr/key/emkts.htm

Keefer, P. (2013). *The Database of Political Institutions 2012*. Washington, DC: Development Research Group, The World Bank. Retrieved from http://go.worldbank.org/2EAGGLRZ40

Kim, L. (1997). Introduction. *Imitation to innovation: The dynamics of Korea's technological learning* (1st ed., pp. 1-10). Boston, MA: Harvard Business School.

Lall, S. (1992). Technological capabilities and industrialization. *World Development, 20*(2), 165-186.

Lucas, R. (1988). On the mechanisms of economic development. *Journal of Monetary Economics, 22*(1), 3-42.

Lundvall, B. Å. (1992). *National systems of innovation: Towards a theory of innovation and interactive learning* (2nd ed.). London: Anthem.

Marshall, M. G., & Jaggers, K. (2011). *Polity IV Project: Political regime characteristics and transitions, 1800-2010*. College Park, MD: Centre for International Development and Conflict Management, University of Maryland. Retrieved from http://www.systemicpeace.org/polity/polity4.htm

Metcalfe, S. (1995). The Economic Foundations of Technology Policy: Equilibrium and evolutionary perspectives. In P. Stoneman (Ed.), *Handbook of the Economics of Innovation and Technological Change* (pp. 409-512). Oxford: Blackwell.

Miller, T., Holmex, K. R., & Feulner, E. J. (2013). *2013 Index of Economic freedom*. Washington, DC: Heritage Foundation.

Nelson, R. R., & Rosenberg, N. (1993). Introduction. In R. R. Nelson (Ed.), *National innovation systems: A comparative analysis* (1st ed., pp. 3-20). New York: Oxford University Press.

Nelson, R. R., & Wright, G. (1992). The rise and fall of American technological leadership: The postwar era in historical perspective. *Journal of Economic Literature, 30*(4), 1931-1964.

OECD. List of OECD member countries - Ratification of the Convention on the OECD. Retrieved February 12, 2013, from http://www.oecd.org/general/listofoecdmembercountries-ratificationoftheconventionontheoecd.htm

OECD. (1996). *The Knowledge-Based Economy*. Paris: OECD Publishing.

OECD. (1997). *National innovation systems*. Paris: OECD Publishing. Retrieved from http://www.oecd.org/science/inno/2101733.pdf

Ohkawa, K., & Rosovsky, H. (1973). *Japanese economic growth: Trend acceleration in the twentieth century*. Stanford, CA: Stanford University Press.

Rodrik, D. (2008). *One Economics, Many Recipes: Globalization, Institutions, and Economic Growth*. Princeton, NJ: Princeton University Press.

Rodrik, D., Subramanian, A., & Trebbi, F. (2004). Institutions rule: The primacy of institutions over geography and integration in economic development. *Journal of Economic Growth, 9*(1), 131-165.

Romer, P. (1990). Endogenous technological change. *Journal of Political Economy, 98*(5), S71-S102.

Sachs, J. D. (2001). Tropical underdevelopment. *NBER WP 8114,*

Schilderinck, J. H. F. (1970). *Factor analysis applied to developed and developing countries* (1st Ed.). Groningen, Netherlands: Rotterdam University Press.

Temple, J., & Johnson, P. A. (1998). Social capability and economic growth. *The Quarterly Journal of Economics, 113*(3), 965-990.

UCLA: Statistical Consulting Group. (2012). Stata annotated output: Factor analysis. Retrieved 04/15, 2013, from http://www.ats.ucla.edu/stat/stata/output/fa_output.htm

UCLA: Statistical Consulting Group. (2012). Stata data analysis examples: Robust regression. Retrieved 05/10, 2013, from http://www.ats.ucla.edu/stat/stata/dae/rreg.htm

Verspagen, B. (1991). A new empirical approach to catching up or falling behind. *Structural Change and Economic Dynamics, 2*(2), 359-380.

Wagner, C. S., Brahmakulam, I., Jackson, B., Wong, A., & Yoda, T. (2004). *Science and technology collaboration: Building capacity in developing countries?* (No. MR-1357.0-WB). Santa Monica, CA: RAND Science and Technology.

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