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Country responsiveness and innovation returns to technological capabilities

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The paper develops a responsiveness-based index for a series of input factors on a specific target variable by means of an extended version of a random coefficient regression approach, and it applies this methodology to the case of countries? innovation performance, where the target variable is the country number of patents (as proxy of ?innovativeness?), and where inputs are chosen according to the literature dealing with the measurement of country technological capabilities.

The novelty of this approach relies on the possibility of extracting from data a country-specific ?reactivity effect? or ?responsiveness? to each single input feeding into the model. Thus, the paper provides a promising approach for ranking countries according to their responsiveness to specific inputs.

As for results on countries? innovation function, besides a (new) ranking of countries, this approach allows also for testing - in an original and straightforward way - the (possible) presence of increasing (decreasing) returns of innovation to technological capabilities. We consider a longitudinal dataset of 42 emerging and advanced countries observed for 13 years for a total of 546 observations.

Our tests conclude that over the countries and the years considered, the innovation function exhibits increasing returns to technological capabilities.

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1. Introduction

A plethora of statistical indicators are currently used worldwide to capture specific socio-economic trends of cities, regions and countries (United Nations, 2007; Bandura, 2008; OECD and EC, 2008). Standard indicators, either single or composite, should be mainly interpreted as "descriptive" objects, as it is widely recognized that they are "snapshots" of the reality they refer to: given their nature, they cannot rely – when considered by themselves - on any "if-then" principle (or "causal" interpretation). In other words, while they may be able to describe well the magnitude and character (i.e., the "level") of certain realities, they are not informative on the "responsiveness" (or "reactivity") of regions, countries, etc. to those specific input factors thought of as affecting the phenomenon the analyst intends to measure.

Therefore, when responsiveness is the main concern, the knowledge of level indicators needs to be accompanied with some measure of how these indicators react to external stimuli and a new approach is thus needed. This paper proposes a method for building an index of country *reactivity* (or *responsiveness*) to specific inputs (suggested by a "theory") when a given target variable, thought of as capturing the phenomenon the analyst wishes to enquiry, is selected. This target variable could be in turn both a composite or a single indicator, depending on the context and data availability.

This proposal should be seen as *complementary* to the standard approach based on "level measurement". In this direction, it can be seen as a way to improve the informational set the analyst and the policymaker may have at his disposal, when a more comprehensive understanding of the phenomenon is demanded.

The approach proposed in this paper to measure responsiveness is based on a statistical tool, the "random coefficient regression", whose first applications have been made in the context of microeconometric program evaluation (or *treatment effect* literature), but that seems suitable and useful to apply also to a macro-context as that considered here. What distinguishes this approach to standard regression applications is the possibility to gauge *observation-specific responsiveness*, an aspect that standard regression models are unable to provide.

The study of responsiveness – as defined above – has a twofold usefulness: (i) it is able to inform policymakers not only on the (static) achieved levels of the countries' performance they wish to look at, but also on the (dynamic) responsiveness patterns that countries could exhibit on specific factors, by allowing a complementary analysis of "level" on one hand, and "reactivity" on the other; (ii) it conveys further statistical tests than those allowed by usual methods, such as the possibility to look at the (possible) presence of increasing (or decreasing) returns for the considered phenomenon, an aspect of the utmost importance especially from a policy perspective.

The application proposed in this work enjoys many of the advantages of this novel approach and, at the same time, it is a suitable example for elucidating its worth. We embed our analysis within the literature on the measurement of "country technological capabilities"[1], providing a new perspective on the subject, that based on *responsiveness* measurement. Indeed, we are interested in estimating a *country innovation function* where an innovation target variable is regressed on a series of technological capabilities' inputs (such as, public and private R&D, number of researchers, material and immaterial infrastructures and so on). Our methodology allows for identifying, for each country, which is the input factor whose modification generates the highest modification in the innovative output. This produces scores that can be then aggregated and compared, thus providing a ranking of countries based on "overall reactivity".

The knowledge of "responsiveness scores" allows for studying the shape of countries' innovation function, as they convey information on the reactivity (mathematically, the *derivatives*) of the function in that input point. As it will be clearer later, an important implication of this, is the

[1] See in particular: Fagerberg and Srholec (2008), Archibugi, Denni and Filippetti (2009), James (2006), Archibugi and Coco (2005), Archibugi and Pietrobelli (2003), Lall (2001).

possibility of testing the presence of increasing (decreasing) returns in the innovation function by a novel method.

The consequences of the proposed approach for policymaking are striking. A policymaker may know not only what is the current state of country technological capabilities, but - as these capabilities are ultimately directed to foster “innovation” - he can also know which is the most reactive countries as well as - within a country - which are the most reactive factors.

In the paper, we consider the case of countries’ innovative performance as captured by the number of patents per 100,000 inhabitants: we will look at the relation between this target variable and a number of input factors usually assumed by the literature as those driving innovative performance. As dataset, we make use of the GloCap indices, an already existing set of indicators of technological capabilities measured on 42 countries. Although we are aware of the limits of patents as appropriate indicators of innovativeness, we deem our exercise to be a valuable first step to analyse this phenomenon within a “responsiveness” approach, and that further improvements will be provided in the near future.

The paper is organized as follows: section 2 discusses the rationale and usefulness of measuring “responsiveness” within our framework; section 3 presents the proposed index of responsiveness and the statistical approach and protocol for its construction. Section 4 provides a description of the data used for the application to the countries’ innovation function. Section 5 shows the main results. Section 6, finally, comments the results and concludes the paper.

2. Rationale and usefulness of measuring “responsiveness”

Providing statistical indicators expressed in “level” is the usual practise to describe a certain phenomenon and no doubt it is felt as the basic (and fair) means to inform policymakers and other stakeholders on the magnitude and character assumed by the phenomenon they are interested in (as well as on its temporal pattern, when more than one single measure over time is provided).

In this sense “level” indicators, both in a single or composite form, are snapshots of the phenomenon they wish to capture, useful to measure and compare across units and over time how phenomena distribute and evolve.

Borrowing metaphorically the case of medicine, previous practice shares some similarities with the case in which a physician uses the levels assumed by temperature, blood tests or electrocardiography figures as indicators to inspect into the general health of a human being. Yet, although these indicators are at the basis of any correct diagnosis, thus being highly informative on the current state of the patients’ wellbeing, physicians are subsequently interested in knowing how patients will react to drugs, environmental factors, life-style etc., that is, on how previous indicators will modify according to a series of external stimuli. In this case, after getting a clear picture of the problem, patient “responsiveness” becomes the main concern.

We can extend this reasoning to socio-economic contexts. At country level, for instance, scholars and policymakers could want to complement information on the “level” assumed by the phenomena they look at, with the knowledge on how they change according to a series of factors that previous literature and/or common sense suggest to have some significant importance in affecting them. Furthermore, they could be interested not only in “aggregate” responsiveness, but rather on country-specific reactivity, as well as a physician’s objective would be more that of detecting patient-specific resilience to external stimuli than general population’s average effects. In other words, idiosyncratic unit-specific responses - if estimable – would be more informative and useful than average assessments, as they convey a substantial additional understanding of the phenomena considered. In this regard, as suggested in the introduction, the study of *responsiveness* should be seen as *complementary* to the study of *level*, as both are carrying different yet related information on the same phenomenon.

The definition, statistical measurement and use of the concept of "responsiveness", has its roots in epidemiology and in the so-called literature on "treatment-effect" estimation (Angrist, 1991; Rothman et al., 2008; Husted et al., 2000). In its basic conceptualization, responsiveness is defined as the effect of a specific treatment variable (generally defined) on a specific target variable, once any potential confounder is ruled out. The treatment variable may be, according to the disciplinary context, a new drug or chemical compound, a new type of physiotherapeutic method, as well as, in the economic context, a monetary support to firms' investment decision and so on.

Our analysis is embedded within a *dose-response setting*, assuming a Random Coefficient approach and observable heterogeneity. We hold that, in our case, unobservable factors are irrelevant for the consistent estimation of the treatment effect[2]. Thus, we provide an individual-specific treatment (or responsiveness) effect, where the outcome variable is country "innovativeness" and the treatment variable is any other factor our theoretical framework (see section 4) assumes to have some role in determining country innovative performance.

3. A responsiveness-based index: a construction protocol

The index proposed in this paper is based on a Random Coefficient Regression, an approach rarely used, but with a promising capacity of being of great usefulness in this context. Random coefficients models are normally applied in microeconomic settings, while few extensions to meso and macro environments were done (Wooldridge, 2002, Ch. 18). Yet, with some modifications to its standard use, our context enjoys all the virtues of this approach as it allows, differently from standard regression, for estimating the unit (country, in our case) specific parameter of interest instead of just an average value across observations. It means that each observation, i.e. each country, gets its own regression parameter that can be assumed to be the *idiosyncratic responsiveness effect* of this country to a specific input factor. To more easily understand how our approach works, we propose to follow this simple protocol, taking as example the case of country innovative performance we will develop later on in the paper :

1. Define the specific object of the analysis: *what one wants to look at* (for instance, "country innovation performance")

2. Define a measure of this phenomenon: *how to gauge it* (for instance, "number of patent per 100,000 inhabitants") and indicate it by y.

3. Define a set of Q factors that a certain theoretical framework (for instance, the "linear model of innovation", the "national systems of innovation" or the "knowledge-based/capabilities" approach) identify as the leading factors affecting country innovative performance, and indicate the generic factor with x_q.

4. Define a "responsiveness model" - by means of a random coefficient regression - linking y to the various x_q, and extract a country-specific measure of "reactivity effect" of y to the all set of $\{x_q , q=1, ..., Q\}$.

5. Aggregate results on reactivity effects across the Q inputs according to some rule and rank countries according to this new generated variable.

[2] This assumption can be relaxed but, as suggested above, Instrumental-Variables are then needed in order to restore consistency. Nevertheless, as we use country level data, this requirement should be less bounding than in microeconomic contexts.

The responsiveness-effect we are interested in, is defined as the "partial effect" of a random coefficient regression (Wooldridge, 1997; 2001; 2002). Define a random coefficient setting of this kind:

$$\begin{cases} y_i = a_{i,q} + b_{i,q} x_{i,q} + e_i \\ a_{i,q} = \gamma_0 + \mathbf{x}_{i,-q}\boldsymbol{\gamma} + u_i \\ b_{i,q} = \delta_0 + \mathbf{x}_{i,-q}\boldsymbol{\delta} + v_i \end{cases}$$

where e_i, u_i and v_i are error terms with $E(e_i \mid x_{i,q}) = E(u_i \mid x_{i,q}) = E(v_i \mid x_{i,q}) = 0$. It is easy to see that the regression parameters, a and b, are both non constant as depending on all the other inputs x except x_q (this is, in fact, the meaning of the vector $\mathbf{x}_{-q}$). Observe that δ_0 and γ_0 are on the contrary constant parameters. According to this model, we can define the *regression line* as:

$$E(y_i \mid x_{i,q}, a_{i,q}, b_{i,q}) = a_{i,q} + b_{i,q} x_{i,q}$$

We define the *responsiveness effect* of $x_{i,q}$ on y_i as the *derivative* of y_i relative to $x_{i,q}$, that is:

$$\frac{\partial}{\partial x_{i,q}} \left[E(y_i \mid x_{i,q}, a_{i,q}, b_{i,q}) \right] = b_{i,q}$$

where $b_{i,q}$ is called the *partial effect* of $x_{i,q}$ on y_i. We can repeat the same procedure for each $x_{i,q}$ (q=1, ..., Q), so that eventually it is possible to define, for each country i =1 ..., N and factor q=1, ..., Q, the N x Q matrix **B** of "partial effects" as follows:

$$\mathbf{B} = \begin{pmatrix} b_{11} & \cdots & b_{1Q} \\ \vdots & b_{i,q} & \vdots \\ b_{N1} & \cdots & b_{NQ} \end{pmatrix}$$

If all the variables are normal-standardized (getting *z-scores*), *partial effects* are *beta coefficients*, so that they are independent of the unit of measurement and can be compared and summed[3]. Thus, a *Composite Partial Effects* (CPE) indicator for a country i based on these responsiveness-effects (partial effects) could be, for instance:

$$CPE_i = \sum_{q=1}^{Q} w_q b_{i,q}$$

It can be interpreted as a weighted average of the single inputs x_q responsiveness effects. The higher this level for a country, the higher the capacity of this country of taking advantage of the increment of its inputs components. It can be proved (see, for instance, Wooldridge, 2002, p. 638-642) that the estimation of $b_{i,q}$ can be achieved, *under no endogeneity problems*, by an Ordinary Least Square (OLS) estimation of this regression:

[3] As beta-coefficients are all measured in standard deviations, instead of the units of the variables, they can be compared to one another. The meaning of this coefficient is straightforward: suppose that in a regression of y on x the beta is found to be equal to 0.3, then it means that one standard deviation increase in x leads to a 0.3 standard deviation increase in the predicted y with all the other variables in the model held constant.

$$y_i = \gamma_0 + \mathbf{x}_{i,-q}\boldsymbol{\gamma} + (\delta_0 + \bar{\mathbf{x}}_{-q}\boldsymbol{\delta})x_{i,q} + x_{i,q}(\mathbf{x}_{i,-q} - \bar{\mathbf{x}}_{-q})\boldsymbol{\delta} + \eta_i$$
$$\eta_i = u_i + x_{i,q}v_i + e_i$$

where $\bar{\mathbf{x}}_{-q}$ is the vector of the sample means of $\mathbf{x}_{i,-q}$. Once previous regression parameters have been estimated by OLS, we can get for the generic country *i* an estimation of the partial effect of variable x_q on *y* as:

$$\hat{b}_{i,q} = \hat{\delta}_0 + \mathbf{x}_{i,-q}\hat{\boldsymbol{\delta}}$$

By repeating this procedure for each *q*, we can finally obtain $\hat{\mathbf{B}}$, that is, the OLS estimation of the *partial effects matrix*[4]. As we will see in section 5, the analysis by row and by column of this matrix is the core of our application.

4. An application to countries' innovation performance

This section presents the indicators used in our application. We exploit a new and updated set of variables capturing country technological capabilities – the GloCap dataset – developed in Filippetti and Peyrache (2010)[5]. It includes nine variables (or sub-indices) for 42 countries that are observed over thirteen years, from 1995 to 2007[6]. Variables are grouped into three main categories or pillars: *Business and Innovation, Knowledge and Skills, Infrastructures*[7]. Table 1 presents the three pillars and the nine variables considered along with their sources.

The GloCap dataset was primarily thought for building a composite indicator of the nine variables feeding into it. But our methodology takes on another perspective, as we have to assume one dependent and eight independent variables (input factors) within the GloCap. Indeed, what we want to estimate is - to some extent - an *innovation function*, where the dependent variable is a measure of country innovativeness, and all the remaining factors are assumed to explain the level of this performance. The logic of this choice seems a reasonable one, as the GloCap captures quite well those basic elements the literature largely consider to be the main drivers of innovation performance. Let us briefly comment on the *output* and *input* indicators considered in this application in the light of innovation and technological capabilities literature.

OUTPUT VARIABLE

Number of patents

Patents have been largely used for accounting commercial purpose generated technological innovation (Griliches, 1990). As such, they can be considered a "tolerable assumption"

[4] The authors have programmed their own STATA 11 program for this purpose. They have planned to provide this program publicly in next future.

[5] The complete dataset is freely available on request to the authors. See also Cerulli and Filippetti (2010) for an application using these data.

[6] We consider essentially emerging and advanced countries. We have excluded low income countries as the dynamics of innovation on one hand and technological capabilities on the other for these are really different and poorly comparable with those of emerging and advanced nations. This is particularly true when patents are assumed to measure innovation performance, as in low income countries innovation could take less codified forms and should be better "understood as the diffusion of technologies and related practices which are new to a given context (not in absolute terms)" (Aubert, 2004, p. 2).

[7] Each variable within each pillar is firstly standardized according to the level of country population.

(Schmookler, 1962) of the innovative activities of firms. We use the "triadic patents" which correspond to patents filed at the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Japan Patent Office (JPO), for the same invention, by the same applicant or inventor (OECD, 2004; OECD, 2008). The advantage of using this particular family of patent is twofold. First, they are a reliable tool for cross-country comparison, given that they include the three more important and natural patent office in the world. Second, the underlying innovation related to a patent filed in the three most important offices across the world is more likely to be valuable (in commercial terms, loosely defined) with respect to an innovation protected only in one single office.

Of course, patents present also some limitations as an innovation indicator. First, patenting intensity can largely differ across industrial sectors (Cohen et al., 2000). Consequently, cross-countries differences in terms of patenting activity can reflect a different industrial structure. Second, patents by definition are not capable to capture service innovation, while in advanced countries services have been dramatically growing in importance in terms of innovation investment and knowledge creation and exploitation. Third, patents captures especially product innovation, thus hiding process and above all organizational innovations that in modern economies are of increasing importance. Four, patents account for codified innovation, while in many industrial contexts innovations take the form of incremental quality changes of products that are rarely patented. Nevertheless, we may accept this variable as a proxy of innovation, although the abovementioned limits and shortcomings.

INPUT VARIABLES

(A) Business innovation effort: *(1) BERD*

As we are looking at the number of patents as our target indicator of innovation, business R&D expenditures (BERD) should be expected to have a fundamental role as the main driver of private innovation performance. R&D activity is not only generally viewed as able to promote innovation via the so-called linear model of innovation (Godin, 2006; 2007), but also because it enlarges the so-called firm *absorptive capacity* (Cohen and Levintal 1989; Rosenberg 1990), thus promoting firm ability to exploit profitably external flows of knowledge and technological advancements. Including BERD is thus of the utmost importance for our purposes.

(B) Knowledge and Skills: *(2) Number of researchers, (3) Number of scientific articles,* and *(4) Public R&D (GOVERD+HERD).*

These variables aim at capturing the importance attached to R&D activities within the economy, the quality of the university and research system, and the public effort for R&D activities. These can be thought of as the knowledge-base of the country innovation system. The variable "total researchers in R&D" is expected to reflect the magnitude of human resources with high-skills involved in formal scientific-based and technological-based activities, both in the public and in the private sector (Howitt, 2000; World Bank, 1998). The variable "scientific and technical articles" represents the magnitude of the generation of codified knowledge. Specifically, it reflects the knowledge generated especially in the universities and public-funded research centres (Etzkowitz and Leydesdorff, 1997). However, it also reflects knowledge generated in the private sector which over the last years have been publishing an increasing share of scientific and technical articles. Finally, Public R&D (GOVERD+HERD) gives account of the resources devoted to formal research activities by the state, including both governmental institutions and higher education institutions.

(C) Infrastructures: *(5) Number of personal computers, (6) Number of fixed-line and mobile phones subscribers, (7) Number of internet users,* and *(8) Stock of fixed capital.*

The importance of material and immaterial infrastructures is also been recognised to be an important condition for countries to innovate and develop (World Bank, 1998). This has increasingly become a necessary requirement with the revolution of the new information and communication technologies (ICTs) which have profoundly changed the way people do things, leading to fundamental changing in the organizational structure of the firm, their business models, the channels for the sharing and diffusion of knowledge and so on (Castells, 1996). Within this environment, being connected has become a necessary condition for countries to access knowledge created and circulated across the globe through the worldwide web (Rifkin, 2000). Both personal computers, fixed-line and mobile phones and the number internet users should capture all together the quality of the network and immaterial infrastructures of a country to tap global knowledge[8]. Additionally, fixed capital accumulation aims at capturing the hard (material) infrastructure which can be key especially at the beginning of catching-up processes.

5. Results

This section provides the results of our analysis. We chose to divide it into two subsections: section 5.1, more descriptive, focuses on the construction of country/factor rankings according to the estimation of the matrix **B** of the responsiveness scores. In this part we consider the two extreme years of the GloCap dataset, 1995 and 2007 respectively, by comparing them to identify potential changes over time; section 5.2, more normative, aims at testing the presence of increasing (decreasing) returns in the country innovation function. For this purpose, we make use of the whole longitudinal dataset, thus relying on 546 observations regarding 42 countries observed over 13 years.

5.1 Responsiveness scores and country/factor rankings

Tables 2.A and 2.B set out the estimation of matrix **B** for 1995 and 2007 respectively. As suggested above, these partial effects are comparable as variables are normal-standardized. Both tables show a strong variability of results across countries, either in terms of magnitude of the effects or in terms of their sign.

The columns and rows with the heading "Total" and "Mean" have two different meanings if read by column or by row: by column, they are the sum by factors of the *b*-coefficients and their average respectively; by row, they are the sum by country of the *b*-coefficients and their average respectively. We comment our results first by column and then by row.

By column

The countries' rankings are visible in the tables and have been obtained by sorting by column on "Mean" (observe that sorting on "Total" brings to the same ranking). The meaning of these two measures is quite straightforward: the total effect is the sum of the single partial effects and represents the "global" responsiveness of the eight inputs on country patenting propensity; the mean effect represents the average of the eight inputs coefficients, and it represents an estimation of CPE_i where the weights are all put equal to 1/8 (i.e., the simple arithmetic mean). Both "Total" and "Mean" convey two different although really correlated information in terms of overall country responsiveness of innovation output to innovation inputs. Results on the rankings show important differences between 1995 and 2007. In 1995 more technologically advanced countries rank within the first positions, while in 2007 this conclusion is partially attenuated. Observe that, on average, some countries present a negative responsiveness of innovation to inputs both in 1995 and 2007.

[8] Initially we also included broadband subscribers, but in this case we decided to rule it out because of a large overlapping with other variables within the same pillar.

The Spearman correlation between these two rankings is significantly low (about 0.20), thus suggesting that a different pattern is at work in the two periods.

Apart from some evident variability in advanced countries (such as, for instance, the case of Ireland passing from position 34 in 1995 to 2 in 2007, Singapore passing from position 9 in 1995 to 43 in 2007, and UK passing from position 17 to 4), the great variability is found in the post-communist European countries: Estonia passes from position 39, where it got a negative sign, to position 13 with a positive sign; Poland passes from position 37 and a negative coefficient to position 21 and a positive coefficient; Slovak Republic passes from position 35 and a negative sign too, to position 8, and Slovenia from 38 to 9 (changing, also in this case, its sign). But also Romania and Bulgaria get higher positions, although still maintaining a negative sign. The so-called BRIC do not seem to have moved substantially: Russia passes from 43 to 41, India from 31 to 34, China remains stable at 32, while only Brazil passes from position 27 to 22 by changing sign. Also interesting is the movement of some developed countries changing significantly their sign from a positive to a negative one: Iceland and Singapore drop to position 42 and 43 respectively, Norway from 18 to 40, and France from 10 to 38.

Generally speaking, what clearly emerges in moving from 1995 to 2007 is a pattern showing that some advanced countries lose momentum in their innovative reactivity to technological inputs, while a specific group of developing countries, the post-communist ones, gain considerable strength.

Similar conclusions can be drawn by looking at tables 3.A and 3.B, where the country ranking is - this time - provided factor by factor (these tables are not reported for reducing the paper length to 10,000 words).

By row

In this case, the meaning of "Total" and "Mean" changes completely, as it becomes the sum and the mean of the partial effects across country. In this case it can be put into evidence which are the factors that contribute more to innovation responsiveness. Table 4 shows both for 1995 and 2007 the ranking of factors according to the "Mean" (observe that the ranking by "Total" leads exactly to the same conclusions). Let's comment on this table.

In 1995 – as expected – the factor generating the highest reactivity to innovation is "BERD", with a mean value of 0.70 and a total value of 30.07. It is followed by "Mobiles&Phones" (mean of 0.30, total of 12.69), "PUBRD" (mean of 0.20, total of 0.82), "Articles" (mean of 0.18, total of 7.89), "Capital" (mean of 0.09 and total of 3.66) and "Researchers" (with the lowest positive impact taking mean 0.02 and total 0.82). It is worth to observe, finally, the very high negative magnitude of the "PC" (mean of -0.74, total of -31.88) and "Internet" (but with a low mean level of -0.05 and total of -2.10).

In 2007 something changes quite radically, although "BERD" remains the most reactive factor (mean of 1.08, total of 46.52). Indeed, "Internet" that had a negative impact in 1995, has now the second positive effect (mean of 0.46, total of 19.66), followed by "Capital" (mean of 0.25, total of 10.78) maintaining a positive sign, and "Articles" (with a low mean of 0.04 and total of 1.73). Quite surprisingly "Mobiles&Phones" - that ranked in the second position with a positive effect in 1995 – ranks in 2007 in the fifth position with a negative sign, followed (always with a negative impact) by "Researchers" (mean of -0.14, total of -5.87), "PC" (mean of -0.33, total of -14.07) and, finally, "PUBRD" (mean of -0.61, total of -26.06).

5.2 Testing for the presence of increasing (decreasing) returns in countries' innovation function

Probably, the most attractive use of the proposed model is that of allowing for testing the potential existence of increasing (or decreasing) returns in countries' innovation function. This is possible since - by the estimation of the various partial effects *b* - we estimate the *derivatives* of the innovation output associated to different levels of innovation inputs. Figure 1 shows two patterns of the innovation function when just one input is at work: one under the case of decreasing returns (figure 1.a), and the other under the case of increasing returns (figure 1.b). It is quite clear to observe that in the first case (decreasing returns), as soon as the level of the input *x* rises, the level of the derivatives (*b*, i.e., the partial effects of our model) decreases accordingly, and the contrary occurs in the opposite case (increasing returns). Therefore, a test for detecting the presence of increasing (or decreasing) returns might be that of studying the relation between the derivatives of the innovation function and the level of the inputs considered. Nevertheless, as many inputs are involved, a synthetic measure of them is firstly needed.

To that end, we proceed as follows: we first calculate a simple composite index of the eight innovation inputs expressed in (standardized) level, thus obtaining a synthetic and unique input measure of innovation input, and then we regress the mean of the partial effects (CPE_i) on this synthetic input variable (we indicate by CI_i). It means that we assume as dependent variable the derivatives of the innovation function, and as the independent one a synthetic innovation input expressed in level. It is quite intuitive that, as soon as the relation between these two variables is significantly increasing, we can conclude that the innovation function exhibits "increasing returns" to innovation input and vice versa (decreasing returns) in the opposite case. As for the eight inputs composite indicator CI_i, we simply use the arithmetic mean of their normal-standardized levels.

To perform this analysis we make use of the longitudinal form of the GloCap dataset, where each of the 42 countries considered is observed for thirteen years, from 1995 to 2007. It means that we can rely on 546 observations, thus achieving a significant sample size for drawing reasonable robust conclusions. Furthermore, the availability of such a kind of database allows both for including lags in the inputs, and for considering "fixed effect estimation" of the innovation function.

Introducing lags might be important as innovation generally comes far after a certain amount of investment in technological capabilities is performed; this might be especially relevant for developing countries where a routinized patenting activity might still be lacking of just in its early stage. Likewise, fixed effects estimation, by assuming that each country starts with a different intercept when all the inputs are set up to zero, seems appropriate to capture country-specific *unobservable elements* that could affect innovation (other than the observable ones already included into the relation between technological capabilities and innovation). Both these aspects seems in tune with a huge literature on the drivers of innovation performance, especially that assuming that aspects such as delays and country-specific institutional, social and cultural elements (sometimes difficult to measure) are considered of primary importance (one may think, for instance, at the "system approach" to national innovative performance).

We consider two different estimations of the innovation function: one with a "contemporaneous" structure between inputs and innovative output and one with a "lag of one year" in the inputs (we do not consider further lags in order to not reduce too much our sample size).

Nevertheless, before setting out results from the longitudinal dataset, it could be useful to study the returns of the innovation function in the two extreme years of our dataset, that is, in 1995 and 2007. In this regard, we use two distinct cross-sections, by making use of both linear regressions and smoothing techniques to enquiry into the relation between CPE_i and CI_i. Results on linear regression are reported in table 5 for both 1995 and 2007, while figure 2 and 3 shows the linear and Lowess fitting for the relation between these two variables.

Results on 1995 shows an impressive significant increasing relationship between the composite indicators of partial effects and the composite indicators of technological capabilities' levels. The OLS linear coefficient is about 0.3 and it is significant at less than 1%. Also the Lowess smoother confirms this result, with a clear upward sloping form of the non-parametric curve. This leads to accept that in 1995 increasing returns to innovation are at work: countries that start with an already consolidated level of innovation inputs (technological capabilities) are also more reactive (for the same increment of input level) than countries lagging behind in terms of input levels. It means that innovative capabilities have a *cumulative* and *self-reinforcing* effect that are able to generate an even more strengthening effect on the capacity to transform innovation inputs into innovative output.

Results on 2007 are a little less clear-cut. We present two estimations, one including all the sample, the other dropping out three visible outliers (Iceland, Singapore e Switzerland). In this second case results are very similar to 1995, although less strong in magnitude than in that case. The regression coefficient, for instance, becomes about 0.10, three times lower than in 1995. But what seems more interesting is the non-parametric form of the curve: in this case it first increases until it reaches a maximum around 0.5 in the input axis, and then it assumes a decreasing pattern. At least roughly, it means that in 2007 the innovation function exhibits increasing returns for low input levels and decreasing ones after a certain threshold is achieved, i.e., for higher technological input levels.

These findings lead to the conclusion that some "structural change" in countries' innovation function was probably at work between 1995 and 2007, and it might be explained by a drop of competitiveness in traditionally more advanced technological countries due to globalization and to the brilliant growth of some developing countries, such as Cina, India and Brazil and above all – as maintained by our comparison of rankings - post-communist countries.

Of course, given the limited size of the sample for the two cross-sections we cannot conclude nothing in terms of robustness. Therefore, it seems useful to go into the longitudinal analysis, where 546 observations are this time employed. Regression results are reported in table 6 and 7, for the "contemporaneous" and the "lagged" structure respectively, while figures 4 and 5 show the linear and smoothed fit for the two models.

Both the contemporaneous and lagged model confirm a positive significant effect of *CI* on *CPE*, thus suggesting with higher robustness that the innovation function estimated in this work exhibits increasing returns. The plots in figure 4 and 5 show that this increasing relation assumes also a strong linear form as the Lowess smoother does not provide considerable differences compared with the interpolated line (also by deleting some evident outliers).

Nevertheless, it is worth stressing that in the longitudinal dataset the magnitude of coefficients is lower than in the cross-section analysis: table 6 shows that the coefficient for the OLS is now about 0.057 when including the whole sample, and 0.066 when excluding outliers, while the fixed effects estimation is in line with OLS, with a significant value of 0.064. In this last case the estimation shows that, as expected, the fixed effects are different from zero thus suggesting differential country-specific starting points.

As for the lagged (one period) longitudinal analysis, figure 5 shows that the increasing shape still continues to exist and it seems to assume a linear form also in this case. Table 7 suggests that coefficients are in line with the contemporaneous model: in the OLS with the whole sample it is about 0.056, in the OLS without outliers it is about 0.061, while the fixed effects estimation provides a smaller value of 0.037 that is significant, but just at 10%.

6. Conclusion

The methodology developed in this paper highlights new insights into the study of countries' innovative performance. The capacity of this model to capture country-specific innovative output's response to innovation inputs – the main original contribution of the paper – seems a useful step forward into a major understanding of how innovative efforts (input of technological capabilities) feed innovation[9].

From our perspective, two main objectives have been achieved: one, more statistical-methodological in nature, regards the proposal of a new (composite) index of (country)

[9] We are aware that part of the literature on technological capabilities assumes that they should be seen just as an output *per se* rather than as an input as we did in this paper.

responsiveness; the other, more in tune with the economics of innovation, allows for building a test detecting the presence of increasing (decreasing) returns in country innovation function.

In terms of results, the paper proves quite clearly the existence of *increasing returns* to technological capabilities' scale, by considering 42 countries in a time span of 13 years. More specifically, while in 1995 increasing returns are strongly evident, they appear more attenuated in 2007, thus showing that a sort of "structural change" is also at work.

Which are the possible causes laying behind these results, and what consequences could they have in terms of innovation (and growth) policy implications? The first point is easier to answer than the second. There is a huge literature and a shared common sense suggesting that innovation processes are inherently cumulative, path-dependent and self-reinforcing, at least to some significant extent.

According to Arthur (1994) and Nelson and Winter (1982) this is what basically makes innovation a process characterized by increasing returns. Innovation processes are indeed profoundly sensitive to all those elements the economic and management literature identify as carriers of increasing returns: path-dependence, threshold mechanisms and spreading costs' effects, increasing specialization and organizational upgrading, continuous movements along the experience and learning curves (*cumulativeness*), scope and diversification economies, network and agglomeration spillovers, market power. All these elements, with different strength depending on the context, contribute to *bandwagon effects* associated to the generation and diffusion of innovation, as also maintained by the New Growth Theory that, from a macroeconomic perspective, describes knowledge creation as having an intrinsic non-rival nature generating spillover effects able to compensate (socially) the high private costs of doing R&D activities (Romer, 1986; 1990). It is for these reasons that innovation processes are potentially more associated with increasing than decreasing returns, and are normally considered at the basis of long-run self-sustained economic growth (Grossman and Helpman, 1991; Aghion and Howitt, 1993).

Nevertheless, it does not mean that innovation processes are exempt from potential deadlocks: the evolutionary perspective has widely recognized the risk connected to *lock-in* patterns and situations of diminishing technological opportunities, as in the case of saturated technological trajectories (Dosi, 1993; Malerba and Orsenigo, 1996; Levinthal, 1996). But these phenomena seem to appear more in micro rather than macro-contexts, where increasing returns to technological capabilities seem to be the general rule.

Form a policy perspective, the presence of increasing returns in innovation open another relevant question regarding the capacity of less technologically advanced countries to converge to rates of growth and technological development comparable to those of richer ones (Barro and Sala-i-Martin, 1997). If we assume innovation to be the engine of economic growth, as the neo-Schumpeterian and New Growth Theory schools of thought firmly hold, then the presence of self-reinforcing mechanisms and scale economies in innovation processes lead to the conclusion that convergence might be - if not impossible - at least questionable, although some part of the literature is also suggesting that free trade, technology transfer, as well as the global redistribution of division of labour, could partially mitigate this process, thus allowing for a wider participation of developing countries to the benefits of increasing returns generated elsewhere (Rivera-Batiz and Romer, 1991; Ben-David and Kimhi, 2004). It is not the intention of this paper to go into this complex subject, but the reduced level of the increasing returns we have found – for instance – in 2007 might be interpret also as a first signal of this change that is in turn linked, ultimately, to the wider and growing phenomenon of globalization of production and innovation. The problem is that this phenomenon might run the risk to be beneficial only for a few number of countries (nowadays, for instance, the so-called BRIC and the post-communist economies), thus generating a sort of *club-convergence*, while worldwide many other countries would be out of the fruitful effect of globalisation, being thus destined to a permanent backwardness unless suitable compensating policies were found and put at work.

References

Angrist, J.D., Imbens, G.W., 1995. Average Causal Response with Variable Treatment Intensity. NBER Technical Working Paper No. 127.

Aghion, P., Howitt P., 1993. A Model of Growth through Creative Destruction. Econometrica 60, 323-351.

Angrist, J.D., 1991. Instrumental Variables Estimation of Average Treatment Effects in Econometrics and Epidemiology. NBER Technical Working Papers No. 0115.

Archibugi, D., Denni, M., Filippetti, A., 2009. The technological capabilities of nations: The state of the art of synthetic indicators. Technological Forecasting and Social Change 76, 917-931.

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

Archibugi, D., Pietrobelli, C., 2003. The Globalisation of Technology and Its Implications for Developing Countries. Windows of Opportunity or Further Burden?. Technological Forecasting and Social Change 70, 861-884.

Arthur, W.B., 1994. Increasing Returns and Path Dependence in the Economy. University of Michigan Press, Ann Arbor.

Aubert, J-E., 2004. Promoting innovation in developing countries: A conceptual framework. World Bank Institute, July.

Bandura, R., 2008. A Survey of Composite Indices Measuring Country Performance: 2008 update. UNDP/ODS Working Paper.

Barro, R.J., Sala-i-Martin, X., 1997. Technological Diffusion, Convergence, and Growth. Journal of Economic Growth 2, 1-26.

Ben-David, D., Kimhi, A., 2004. Trade and the rate of income convergence. Journal of International Trade & Economic Development 13, 419-441.

Castells, M., 1996. The Rise of the Network Society: The Information Age: Economy, Society and Culture. Vol 1. The Information Age Blackwell Publisher, Oxford.

Cerulli, G., Filippetti, A., 2010. The usefulness of STI composite indicators: an empirical application to 42 countries. The ENID Conference, March 2010, Paris.

Cohen, W.M., Nelson, R.R., Walsh, J.P., 2000. Protecting their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (or not). NBER Working Paper No. 7552.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and Learning: The Two Faces of R&D. The Economic Journal 99, 569–96.

Dosi, G., 1993. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. Research Policy 22, 102-103.

Etzkowitz, H., Leydesdorff, L., (Eds.) 1997. Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations. Cassell Academic, London.

Fagerberg, J., Srholec, M., 2008. National innovation systems, capabilities and economic development. Research Policy 37, 1417-1435.

Filippetti, A., Peyrache, A., 2010. The patterns of technological capabilities of countries: A dual approach using composite indicator and data envelopment analysis. World Development, forthcoming.

Godin, B., 2006. The Linear Model of Innovation: The Historical Construction of an Analytical Framework. Science, Technology, and Human Values 31, 639-667.

Godin, B., 2007. Science, Accounting and Statistics: the Input-Output Framework. Research Policy 36, 1388-1403.

Griliches, Z., 1990. Patent Statistics as Economic Indicators: a Survey. Journal of Economic Literature 28, 1661-1707.

Grossman, G.M., Helpman, E., 1991. Innovation and Growth in the Global Economy. MIT Press, Cambridge, MA.

Heckman, J.J., Urzua, S., Vytlacil E., 2006. Understanding Instrumental Variables in Models with Essential Heterogeneity 88, 389-432.

Howitt, P., 2000. Endogenous Growth and Cross-country Income Differences. American Economic Review 90, 829–846.

Husted, J.A., Cook, R.J., Farewell, V.T., Gladman, D.D., 2000. Methods for assessing responsiveness: a critical review and recommendations. Journal of Clinical Epidemiology 53, 459–468.

James, J., 2006. An Institutional Critique of Recent Attempts to Measure Technological Capabilities across Countries. Journal of Economic Issues 40, 743-766.

Lall, S., 2001. Competitiveness Indices and Developing Countries: An Economic Evaluation of the Global Competitiveness Report. World Development 29, 1501-1525.

Levinthal, D., 1996. Learning and Schumpeterian Dynamics, in: Dosi, G., Malerba, F. (Eds), Organization and Strategy in the Evolution of the Enterprise. Macmillan, New York.

Malerba, F., Orsenigo, L., 1996. The Dynamics and Evolution of Industries. Industrial and Corporate Change 5, 51-87.

Nelson, R.R., Winter, S.G., 1982. An Evolutionary Theory of Economic Change. Harvard University Press.

OECD 2004. Triadic patent families methodology. OECD, Paris.

OECD 2008. Compendium of patent statistics. OECD, Paris.

OECD, EC-European Commission 2008. Handbook on Constructing Composite Indicators: Methodology and User Guide. OECD, Paris.

Rifkin, J., 2000. The Age of Access: The New Culture of Hypercapitalism, Where all of Life is a Paid-For Experience. Penguin, London.

Rivera-Batiz, L., Romer, P.M. 1991. International trade with endogenous technological change, European Economic Review 35, 971-1001.

Romer, P., 1986. Increasing Returns and Long-term Growth. Journal of Political Economy 94, 1002-1037.

Romer, P. 1990. Endogenous Technological Change. Journal of Political Economy 98, S71-S102.

Rosenberg, N., 1990. Why do firms do basic research (with their own money)?. Research Policy 19, 165-174.

Rosenbaum, P.R., Rubin, D.B., 1983. The central role of the propensity score in observational studies for causal effects. Biometrika 70, 41-55.

Rothman, K.J., Greenland, S., Lash, T.L., 2008. Modern Epidemiology. 3rd Edition. Lippincott, Williams & Wilkins.

Rubin, D., 1974. Estimating Causal Effects of Treatments in Randomized and Nonrandomized Studies. Journal of Education Psychology 66, 688-701.

Schmookler, J., 1962. Economic sources of inventive activity. The Journal of Economic History 2.

United Nations, 2007. Indicators of Sustainable Development: Guidelines and Methodologies. Third Edition. New York.

Wooldridge, J.M., 1997. On two stage least squares estimation of the average treatment effect in a random coefficient model. Economics Letters 56, 129–133.

Wooldridge, J.M., 2001. Unobserved Heterogeneity and Estimation of Average Partial Effects. Michigan State University, Department of Economics, mimeo.

Wooldridge, J.M., 2002. Econometric Analysis of Cross Section and Panel Data. MIT Press, Cambridge, MA.

World Bank, 1998. World Development Report. Knowledge for Development. The World Bank, Washington.

Table 1. The three pillars and nine variables feeding into the GloCap index, and the relative data sources.

Pillar		**Variable**	**Data Source**
Business innovation	y	Triadic patents	OECD
	x_1	Business R&D (BERD)	OECD, UNCTAD
Knowledge&skills	x_2	Total researchers in R&D (FTE)	OECD
	x_3	Scientific and technical articles	WDI (World Bank)
	x_4	Public R&D (PUBRD): Government Intramural Expenditure on R&D (GOVERD) + Higher Education Expenditure on R&D (HERD)	OECD, UNCTAD
Infrastructures	x_5	Personnel computers	WDI (World Bank)
	x_6	Fixed-line and mobile telephones	WDI (World Bank)
	x_7	Internet users	WDI (World Bank)
	x_8	Fixed capital	WDI (World Bank)

Table 2.A. 1995 – OLS estimation of the country Partial Effects from the random coefficient model.

	Country	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	Total	Mean
1	Switzerland	1.61	1.37	0.99	1.34	0.09	2.16	1.16	0.85	**9.58**	**1.20**
2	Japan	1.70	0.18	0.29	1.67	-1.03	2.95	1.19	0.65	**7.60**	**0.95**
3	Israel	1.02	1.76	0.02	0.21	0.30	1.09	1.52	1.14	**7.06**	**0.88**
4	Sweden	0.86	0.67	0.60	0.21	-0.26	0.66	1.17	0.99	**4.90**	**0.61**
5	Netherlands	1.34	0.62	0.36	0.70	-0.41	1.08	0.44	0.59	**4.73**	**0.59**
6	Austria	1.35	-0.06	0.52	1.02	-0.41	1.17	-0.19	0.55	**3.97**	**0.50**
7	Finland	1.39	0.68	1.09	0.67	-1.18	0.77	0.31	-0.27	**3.45**	**0.43**
8	Germany	1.05	-0.22	0.30	0.77	-0.57	1.12	0.18	0.62	**3.26**	**0.41**
9	Singapore	1.29	-0.08	0.82	1.12	-0.72	1.09	-0.48	-0.16	**2.88**	**0.36**
10	France	0.93	-0.31	0.01	0.47	-0.52	0.81	0.26	0.89	**2.53**	**0.32**
11	Denmark	0.98	0.20	0.43	0.38	-0.32	0.25	0.13	0.38	**2.43**	**0.30**
12	Belgium	0.74	0.25	0.41	0.38	-0.45	0.56	0.15	0.22	**2.26**	**0.28**
13	Italy	1.09	-0.24	0.24	0.60	-0.52	0.66	-0.24	0.59	**2.17**	**0.27**
14	Spain	0.98	0.06	0.22	0.47	-0.58	0.59	-0.16	0.30	**1.89**	**0.24**
15	UE27	0.79	-0.03	0.16	0.30	-0.61	0.46	0.04	0.36	**1.46**	**0.18**
16	Greece	1.10	-0.32	0.33	0.52	-0.70	0.42	-0.47	0.38	**1.26**	**0.16**
17	United Kingdom	0.45	0.44	0.13	-0.23	-0.26	-0.19	0.41	0.41	**1.16**	**0.14**
18	Norway	1.04	-0.21	0.57	0.51	-0.82	0.24	-0.19	-0.05	**1.11**	**0.14**
19	Canada	0.61	0.25	0.12	-0.15	-0.45	-0.17	0.34	0.37	**0.93**	**0.12**
20	New Zealand	0.81	0.23	0.36	0.09	-0.48	-0.32	-0.40	-0.10	**0.19**	**0.02**
21	United States	0.52	-0.22	0.75	0.10	-0.99	0.00	0.08	-0.11	**0.13**	**0.02**
22	Czech Republic	0.55	0.06	0.12	0.07	-0.84	0.22	-0.19	-0.10	**-0.11**	**-0.01**
23	Korea, Rep.	0.70	-0.79	0.33	0.49	-1.00	0.49	-0.47	0.08	**-0.17**	**-0.02**
24	Portugal	0.88	-0.46	0.28	0.41	-0.93	0.26	-0.65	-0.03	**-0.23**	**-0.03**
25	Australia	0.81	-0.27	0.12	0.09	-0.06	-0.63	-0.82	0.31	**-0.46**	**-0.06**
26	Iceland	1.02	-0.46	-0.02	0.21	-1.41	0.16	-0.05	-0.08	**-0.62**	**-0.08**
27	Brazil	0.46	-0.14	-0.01	0.05	-0.82	0.15	-0.49	-0.09	**-0.88**	**-0.11**
28	Turkey	0.58	-0.32	0.12	0.11	-0.82	0.04	-0.63	-0.01	**-0.91**	**-0.11**
29	South Africa	0.44	-0.03	0.11	-0.01	-0.82	0.02	-0.52	-0.22	**-1.03**	**-0.13**
30	Hungary	0.42	-0.02	-0.02	-0.13	-0.83	-0.08	-0.27	-0.11	**-1.04**	**-0.13**
31	India	0.29	0.05	-0.08	-0.16	-0.86	-0.01	-0.41	-0.27	**-1.44**	**-0.18**
32	China	0.26	0.01	-0.09	-0.18	-0.92	-0.04	-0.38	-0.31	**-1.66**	**-0.21**
33	Mexico	0.36	-0.22	-0.01	-0.08	-0.83	-0.12	-0.61	-0.20	**-1.71**	**-0.21**
34	Ireland	0.29	-0.31	0.31	-0.10	-0.64	-0.46	-0.60	-0.24	**-1.75**	**-0.22**
35	Slovak Republic	0.18	0.10	-0.22	-0.39	-0.95	-0.24	-0.01	-0.30	**-1.83**	**-0.23**
36	Argentina	0.19	-0.16	-0.07	-0.21	-1.07	-0.05	-0.19	-0.35	**-1.91**	**-0.24**
37	Poland	0.23	-0.01	-0.19	-0.30	-0.98	-0.19	-0.21	-0.32	**-1.96**	**-0.25**
38	Slovenia	0.34	-0.45	-0.23	-0.18	-1.12	-0.15	-0.23	-0.19	**-2.21**	**-0.28**
39	Estonia	0.38	-0.16	0.08	-0.21	-1.16	-0.34	-0.40	-0.51	**-2.32**	**-0.29**
40	Bulgaria	0.24	-0.24	-0.15	-0.36	-1.05	-0.38	-0.23	-0.24	**-2.41**	**-0.30**
41	Romania	0.11	-0.14	-0.19	-0.37	-1.10	-0.25	-0.25	-0.41	**-2.60**	**-0.32**
42	Lithuania	0.15	-0.34	-0.30	-0.42	-1.23	-0.38	-0.20	-0.39	**-3.09**	**-0.39**
43	Russian Fed.	-0.46	0.08	-0.71	-1.07	-1.56	-0.75	0.46	-0.98	**-5.00**	**-0.62**
	Total	**30.07**	**0.82**	**7.89**	**8.42**	**-31.88**	**12.69**	**-2.10**	**3.66**		
	Mean	**0.70**	**0.02**	**0.18**	**0.20**	**-0.74**	**0.30**	**-0.05**	**0.09**		

Table 2.B. 2007 – OLS estimation of the country Partial Effects from the random coefficient model.

	Country	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	Total	Mean
1	Switzerland	1.55	0.63	0.67	-0.35	0.78	1.12	1.86	0.90	**7.15**	**0.89**
2	Ireland	2.02	0.91	0.65	-0.37	-0.28	-0.53	1.74	0.17	**4.31**	**0.54**
3	Belgium	1.45	0.23	0.40	-0.46	0.17	0.33	0.99	0.54	**3.64**	**0.45**
4	United Kingdom	1.24	0.11	0.37	-0.37	0.10	0.64	0.97	0.48	**3.53**	**0.44**
5	Netherlands	1.14	-0.09	0.43	-0.21	0.07	0.78	0.83	0.54	**3.49**	**0.44**
6	Denmark	1.59	0.16	0.13	-0.45	-0.44	0.07	0.69	0.65	**2.39**	**0.30**
7	Sweden	0.90	0.08	0.12	-0.55	-0.14	0.49	0.71	0.70	**2.32**	**0.29**
8	Slovak Republic	1.35	0.02	0.30	-0.55	0.03	0.03	0.73	0.25	**2.14**	**0.27**
9	Slovenia	1.21	-0.18	0.01	-0.63	-0.02	0.25	0.61	0.47	**1.71**	**0.21**
10	Israel	0.44	0.08	-0.06	-0.90	0.33	0.64	0.77	0.41	**1.70**	**0.21**
11	New Zealand	1.35	-0.38	-0.13	-0.58	-0.13	0.44	0.40	0.69	**1.65**	**0.21**
12	Spain	1.51	0.16	0.20	-0.50	-0.44	-0.34	0.80	0.15	**1.55**	**0.19**
13	Estonia	1.31	-0.05	0.20	-0.45	-0.30	0.20	0.40	0.17	**1.47**	**0.18**
14	Italy	1.19	-0.07	0.26	-0.37	-0.29	0.19	0.50	0.05	**1.47**	**0.18**
15	Japan	1.31	0.55	0.31	-0.72	-0.50	-0.86	0.86	0.36	**1.31**	**0.16**
16	Korea, Rep.	1.19	0.24	0.35	-0.59	-0.35	-0.39	0.51	0.33	**1.29**	**0.16**
17	Hungary	1.05	-0.28	0.20	-0.54	0.05	0.29	0.28	0.20	**1.24**	**0.16**
18	UE27	1.13	-0.05	0.15	-0.50	-0.34	0.00	0.51	0.20	**1.09**	**0.14**
19	Greece	1.32	-0.11	-0.04	-0.62	-0.27	-0.03	0.56	0.10	**0.92**	**0.11**
20	United States	0.97	0.17	0.17	-0.62	-0.52	-0.39	0.63	0.40	**0.82**	**0.10**
21	Poland	1.04	-0.32	0.10	-0.61	-0.00	0.16	0.25	0.15	**0.77**	**0.10**
22	Brazil	0.78	-0.48	0.19	-0.64	0.24	0.05	0.33	0.12	**0.59**	**0.07**
23	Austria	1.02	0.08	0.18	-0.50	-0.62	-0.32	0.49	0.20	**0.54**	**0.07**
24	Mexico	0.84	-0.37	0.09	-0.75	0.18	-0.17	0.53	0.06	**0.40**	**0.05**
25	Germany	0.92	-0.02	0.20	-0.43	-0.69	-0.15	0.17	0.10	**0.10**	**0.01**
26	Portugal	1.17	-0.15	-0.09	-0.70	-0.39	-0.14	0.29	0.09	**0.08**	**0.01**
27	Canada	0.84	-0.63	-0.26	-0.53	-0.55	0.13	0.30	0.61	**-0.09**	**-0.01**
28	Finland	1.17	-0.04	-0.27	-0.80	-0.75	-0.35	0.20	0.72	**-0.11**	**-0.01**
29	Romania	0.91	-0.26	0.01	-0.74	-0.14	-0.26	0.43	-0.08	**-0.12**	**-0.02**
30	Czech Republic	0.98	-0.26	-0.03	-0.66	-0.36	-0.12	0.18	0.14	**-0.12**	**-0.02**
31	Bulgaria	0.97	-0.26	-0.04	-0.72	-0.26	-0.11	0.17	-0.08	**-0.32**	**-0.04**
32	China	0.75	-0.48	-0.11	-0.90	0.14	-0.28	0.42	0.12	**-0.35**	**-0.04**
33	Argentina	0.93	-0.11	-0.07	-0.89	-0.21	-0.45	0.40	0.02	**-0.37**	**-0.05**
34	India	0.51	-0.75	-0.13	-0.92	0.41	-0.18	0.42	0.17	**-0.47**	**-0.06**
35	Australia	0.85	-0.95	-0.17	-0.24	-0.65	0.43	-0.16	0.29	**-0.60**	**-0.07**
36	Lithuania	1.08	-0.29	-0.00	-0.58	-0.57	-0.21	-0.08	-0.07	**-0.73**	**-0.09**
37	Turkey	0.70	-0.52	-0.15	-0.81	-0.10	-0.18	0.22	-0.03	**-0.88**	**-0.11**
38	France	0.95	-0.19	-0.15	-0.64	-0.82	-0.57	0.40	0.12	**-0.89**	**-0.11**
39	South Africa	0.62	-0.51	-0.18	-0.89	-0.04	-0.28	0.34	-0.07	**-1.01**	**-0.13**
40	Norway	1.53	-0.16	-0.07	-0.30	-1.55	-0.96	0.07	0.23	**-1.20**	**-0.15**
41	Russian Fed.	0.96	-0.31	-0.51	-1.03	-0.75	-0.74	0.07	-0.03	**-2.33**	**-0.29**
42	Iceland	1.53	-0.15	-0.68	-0.68	-2.35	-1.86	-0.17	0.06	**-4.28**	**-0.54**
43	Singapore	0.25	-0.86	-0.83	-0.77	-1.76	-0.68	-0.94	0.19	**-5.40**	**-0.68**
	Total	**46.52**	**-5.87**	**1.73**	**-26.06**	**-14.07**	**-4.32**	**19.66**	**10.78**		
	Mean	**1.08**	**-0.14**	**0.04**	**-0.61**	**-0.33**	**-0.10**	**0.46**	**0.25**		

Table 4. Ranking of factors according to their Mean and Total responsiveness effect.

	1995	Total	Mean		2007	Total	Mean
1	BERD	30.07	0.70	1	BERD	46.52	1.08
2	Mobiles&Phones	12.69	0.30	2	Internet	19.66	0.46
3	PUBR&D	8.42	0.20	3	Capital	10.78	0.25
4	Articles	7.89	0.18	4	Articles	1.73	0.04
5	Capital	3.66	0.09	5	Mobiles&Phones	- 4.32	- 0.10
6	Researchers	0.82	0.02	6	Researchers	- 5.87	- 0.14
7	Internet	- 2.10	- 0.05	7	PC	- 14.07	- 0.33
8	PC	- 31.88	- 0.74	8	PUBR&D	- 26.06	- 0.61

Figure 1. Increasing and decreasing returns in an innovation production function.

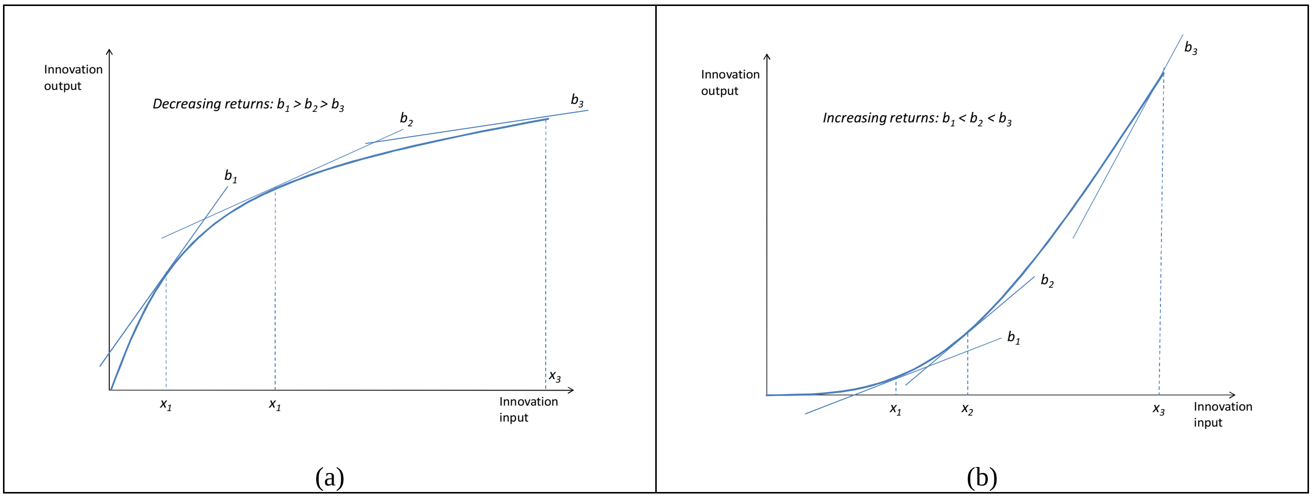


Table 5. Regression line estimation. Dependent variable: "Composite indicators of countries' partial effects" (*CPE*). Independent variable: "Composite indicator of countries' innovation inputs in levels" (*CI*). Note: (1) = results on the overall 1995 sample; (2) = results on the overall 2007 sample; (3) results on 2007 sample excluding three outliers: Switzerland, Iceland and Singapore. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Dep. var.: *CPE*	(1) 1995	(2) 2007	(3) 2007
CI	0.31^{***}	0.05	0.10^{***}
	(0.047)	(0.047)	(0.032)
N	43	43	40
adj. R^2	0.49	0.03	0.17
F-test	42.89^{***}	0.255	8.92^{***}

Table 6. Panel regression with "contemporaneous" inputs. Dependent variable: "Composite indicators of countries'

partial effects" (*CPE*). Independent variable: "Composite indicator of countries' innovation inputs in levels" (*CI*). Note: OLS 1 = OLS results on the overall sample; OLS 2 = OLS results on the without outliers; FE: fixed-effects estimation. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parenthesis.

Dep. var.: *CPE*	(OLS 1)	(OLS 2)	(FE)
CI	0.057^{***}	0.066^{***}	0.064^{***}
	(0.008)	(0.006)	(0.021)
N	546	520	520
adj. R^2	0.08	0.18	0.18
F-test	52.11^{***}	119.6^{***}	9.40^{**}

Table 7. Panel regression with "lagged" inputs. Dependent variable: "Composite indicators of countries' partial effects" (*CPE*). Independent variable: "Composite indicator of countries' innovation inputs in levels" (*CI*). Note: OLS 1 = OLS estimation on the overall sample; OLS 2 = OLS estimation without outliers; FE: fixed-effects estimation. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parenthesis.

Dep. var.: *CPE*	(OLS 1)	(OLS 2)	(FE)
CI	0.056^{***}	0.061^{***}	0.037^{***}
	(0.008)	(0.006)	(0.021)
N	504	520	520
adj. R^2	0.08	0.16	0.16
F-test	45.75^{***}	93.12^{***}	3.10^{*}

Figure 2. 1995 – Linear (a) and Lowess (b) fitting for the relation between the "Composite indicator of countries' innovation inputs in levels" (*CI*) and the "Composite indicators of countries' partial effects" (*CPE*).

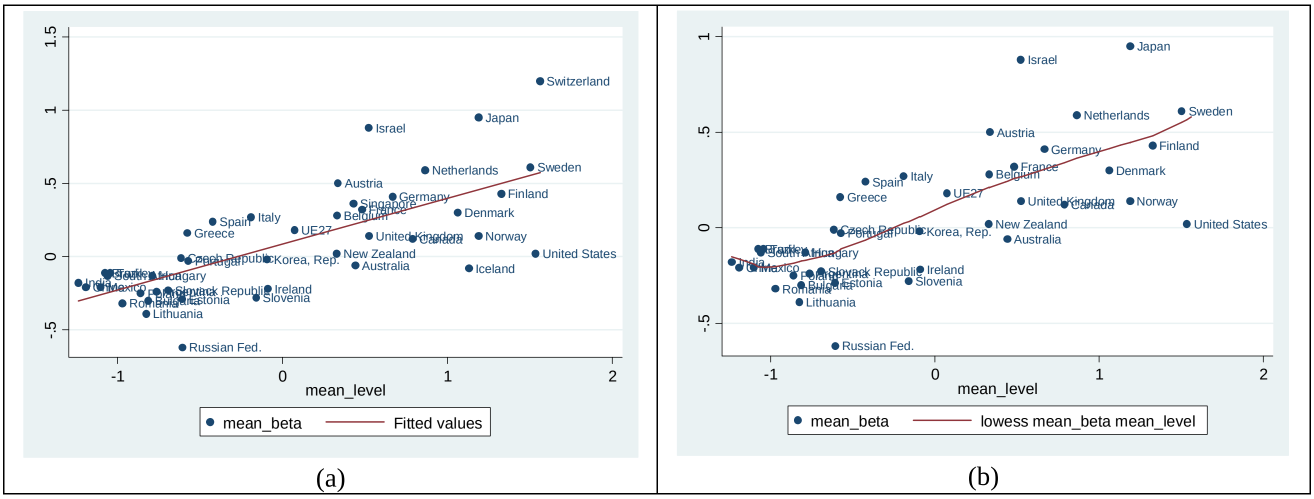


Figure 3. 2007 – Linear (a, c) and Lowess (b, d) fitting for the relation between the "Composite indicator of countries' innovation inputs in levels" (*CI*) and the "Composite indicators of countries' partial effects" (*CPE*). Figures (c) and (d) are drawn by excluding three outliers: Switzerland, Iceland and Singapore.

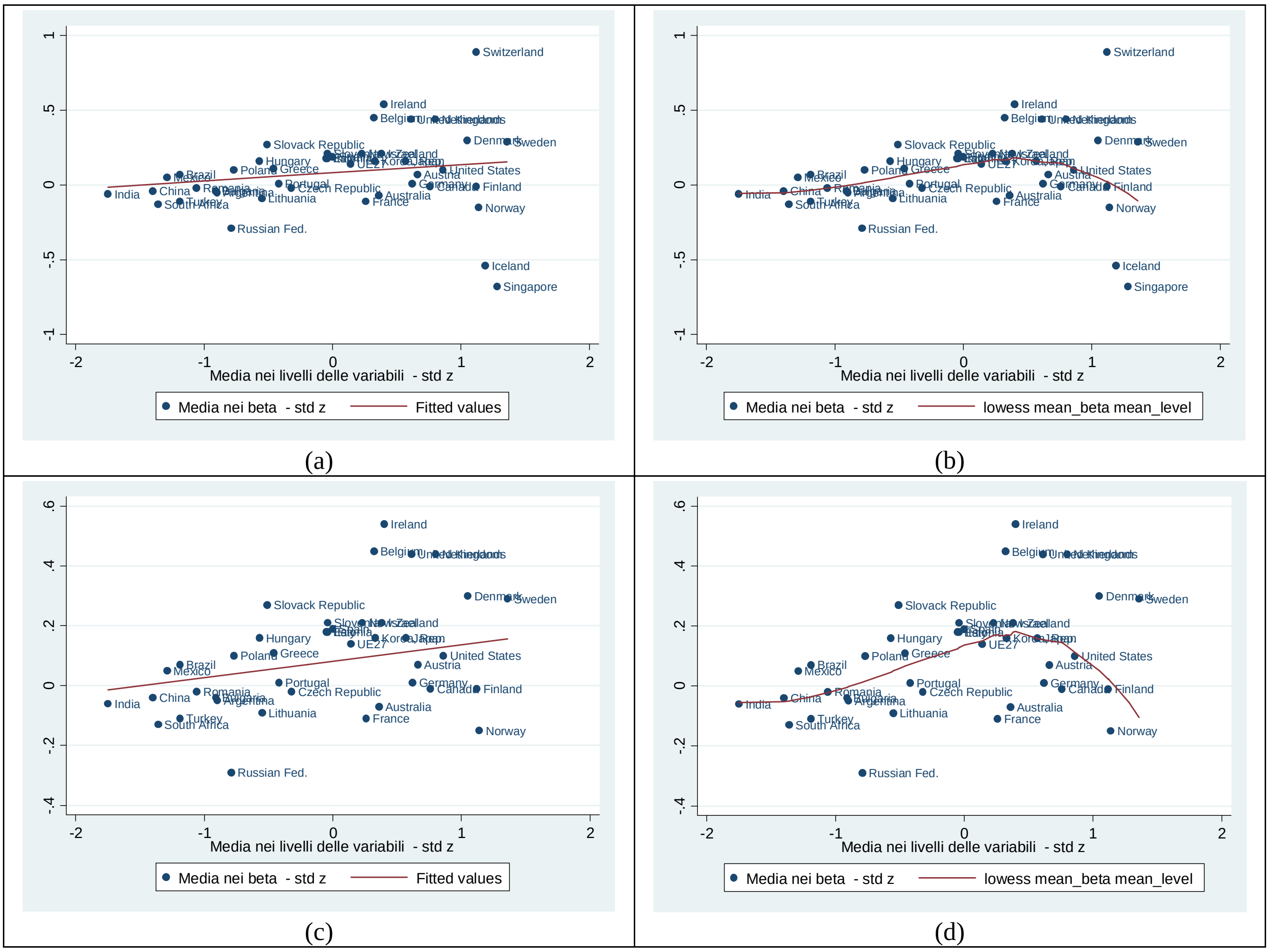
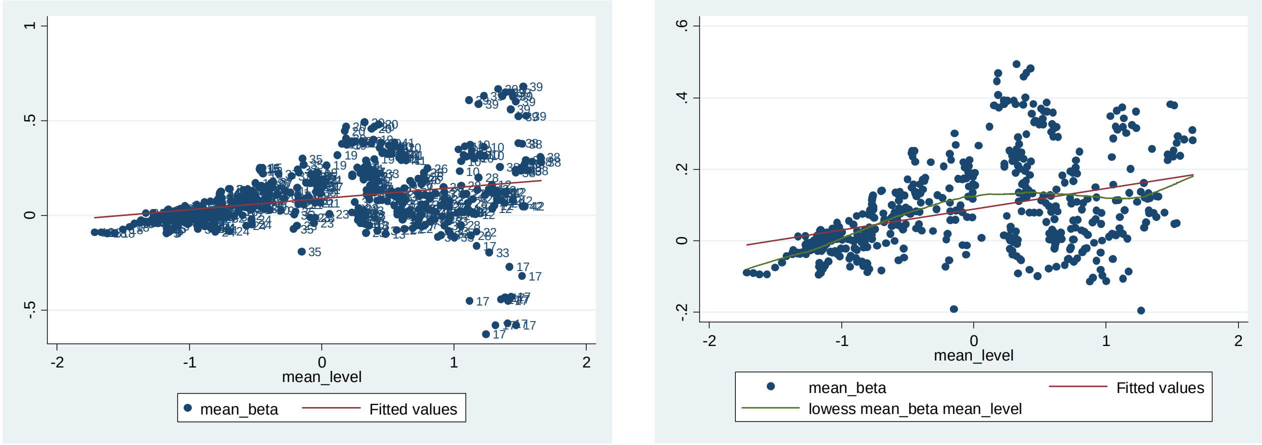


Figure 4. Linear and Lowess fitting for the “contemporaneous” relation between the “Composite indicator of countries’ innovation inputs in levels” (*CI*) and the “Composite indicators of countries’ partial effects” (*CPE*). Figure (a): whole sample. Figure (b): without outliers.



(a) (b)

Figure 4. Linear and Lowess fitting for the “lagged” relation between the “Composite indicator of countries’ innovation inputs in levels” (*CI*) and the “Composite indicators of countries’ partial effects” (*CPE*). Figure (a): whole sample. Figure (b): without outliers.

(a) (b)