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Capabilities, Innovation and Economic Growth in EU Regions

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ABSTRACT
This article discusses the links between human development, innovation and economic growth. After a brief theoretical preamble, I present a framework bringing together the relationships between those processes in a circular causation diagram. I then examine these relationships using data on 266 European regions covering the period 2000–2015. I test two econometric models: one based on panel (3SLS), the other on spatial analysis (SAR). The first helps me explore, in more detail, the relationship between innovation, human development and income. The results indicate a mutually reinforcing relationship between them. The associations between human development and innovation, and GDP and innovation are found to be particularly strong. The spatial analysis further confirms the existence of virtuous circles and the presence of spatial interrelationships, both in terms of spillover and feedback effects. Consequently, I argue, these variables should be promoted simultaneously. I highlight two points that seem especially worthy of being developed in future work: the importance of setting human development as the ultimate goal of innovation policy, and the need to formulate macroeconomic policies fostering innovation and human development.

KEYWORDS
Human development; innovation; economic growth; regional development; spatial econometrics; panel analysis

Background

The Interconnections

Recently, several authors have tried to explore more deeply the relationship between innovation and human development (Ranis and Zhao 2013; Capriati 2013, 2018; Hartmann 2014; Bajmócy and Gébert 2014; Bajmócy, Málovics, and Gébert 2014; Ziegler, Karanja, and Dietsche 2013; Ziegler 2010; Chiappero-Martinetti, Houghton Budd, and Ziegler 2017; Qureshi et al. 2020; Azuh et al. 2020). These works have tried to focus on the possible interactions between the two strands of economic literature. In particular, they have focused on the one hand, on the contribution that improving the capabilities of

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individuals and communities can give to the processes of innovation and, on the other, on the impact of productive and social changes on the expansion of the capabilities of individuals and of groups. These two lines of economic analysis and practice, which follow very different intellectual and practical paths, have many interesting connections in the common ground of economic development.

The central objective of the Capability Approach (CA) is to expand the freedom that deprived people have to enjoy different ways of being and doing; this goal leads us to regard progress in the economic, technological and social fields as simple *means* for the attainment of the ultimate goal of human development. The CA is characterised by being a powerful normative tool for *outcome evaluation*; but it gives little emphasis to the *processes* that lead to a greater economic growth, technical progress and social modernisation.

Conversely, the Innovation System (IS) theory mostly focuses on *processes*. The idea of change considers innovation to be strongly dependent on cultural and *historical contexts* (*path dependence*), the role of *institutions*, political choices, the ability that individuals and companies have *to interact and learn*, as well as mutual trust (*social capital*). Symmetrically, this attention to the process overshadows the *assessment on innovation outcomes*. Not all innovation is good. The outcomes of the innovation process, i.e. more productivity, more efficiency, more competitiveness, do not always translate into improved well-being of people or a good distribution of the benefits and costs involved.

The core conclusion of these studies is that the capabilities approach and the human development theory can provide a normative framework for the development of the social and institutional context in which innovation systems (ISs) develop and that ISs approach can offer a strategy for growth which is conducive to the expansion of capabilities.

Human development scholars have shown some interest in the topic of technological change. It is worth mentioning that Sen addressed this topic in his doctoral thesis entitled *Choice of Techniques* (1960), and in an essay entitled "Employment, Technology and Development" (1975). However, both works were outside the capabilities approach and focused mainly on capital accumulation and employment. Similarly, Frances Stewart (1977), another important capabilities approach scholar, tackles the issue in her *Technologies and underdevelopment*, paying particular attention to the impact that "appropriate" technologies can have on economies in the early stages of their development.

Within the capabilities approach, we can find a line of analysis of technological development which includes Sen's famous example of the bicycle, and, more recently, the cell phone (2010). These examples show that using tools may or may not extend the freedom of individuals. For the CA, technology is a means of achieving a certain capacity to improve one's life. Technology, therefore, has important repercussions on individuals' freedom to be and to do. This is the starting point for the idea that new tools or "artefacts" can play a central role in the interaction between the economy, society and the freedom of individuals, and must be subject to careful evaluation and scrutiny.

The first important contribution to the analysis of the technology/human development nexus came from the HDR (Human Development Report) 2001 (UNDP 2001). According to the authors of this report, many people fear that new technologies may be of little use in developing countries; or that they could expand the already extreme inequalities between North and South and between the rich and the poor. These views assume a direct link between access to technological innovation and the level of income: the wealthier one is, the more technologies one can have. However, the inverse relationship is also true: greater availability of technologies and training provides people with more tools to improve their standard of living. The Report outlines how technology is a tool, not just a result of growth and development, and how technologies, if well targeted to the real needs of the community, have a multiplier effect and create a virtuous circle: they increase people's health, knowledge and productivity, thereby augmenting people's income and, by improving human development, creating future innovative capacities.

Some scholars (Oosterlaken 2015, 2011; Kleine 2013; Oosterlaken and van den Hoven 2012), especially philosophers of science, have taken up these issues and have found that the relationship between technology and human capabilities is relevant, for two main reasons. First, as it has already been pointed out, technology is an important factor in the expansion of human capabilities. Prefabricated homes rapidly ensure access to adequate shelter in areas lacking decent housing; means of transport such as cars, bicycles and public transportation allow individuals to move freely from place to place; the means of communication such as telephones, internet connections, etc. allow people to be involved in various forms of social interaction; and so on (Oosterlaken 2011). Second, because the CA provides a useful tool for evaluating the impact of technologies introduced by development projects, such as evaluating ICT projects or assessing healthcare technologies or biotechnologies (Oosterlaken 2011; Coeckelbergh 2011).

In these contributions, the emphasis is on technology as "a set of material artefacts or systems of such artefacts" (Oosterlaken 2011, 426) and the main goal is understanding the relationship between technology and social and individual change. In this regard, an important contribution of this school of thought is the critical assessment of technology transfer processes, which highlights that "many of the past cases of failed technology transfer to developing countries are a perfect illustration of the fact that technologies do not expand human capabilities without the required interdependencies with people, social structures and other artefacts being present in the recipient country" (Oosterlaken 2011, 431).

Hartmann (2014) adopted a particular perspective in the empirical examination of the relationship between innovation and human development. In his work, he analyses the relationship between diversification "defined as the change in the degree, type, composition and quality of the economic sectors in an economy" (p. 63), and human development. Diversification can be seen as an aspect of the broadest process of institutional and technological change, resulting in an expansion of job opportunities and quality and quantity of goods. This expansion of opportunities, brought about by diversification, has a profound influence on people's capabilities. Greater diversification determines wider opportunities of agency and well-being. According to the author, a person living in a context where fewer goods are produced has fewer employment opportunities than a person living in a context where there are many companies engaged in various activities requiring a high degree of specialised knowledge.

Another strand of literature that has dealt with the relationship between human capabilities and innovation is the one exploring the field of social innovation understood as "the development and delivery of new ideas and solutions (products, services, models, modes of provision, processes) at different socio-structural levels that intentionally seek to change power relations and improve human capabilities, as well as the processes via which these solutions are carried out" (Nicholls and Ziegler 2015). These contributions seek to explore changes in social relationships, especially in the many parts of the world where trust has collapsed and rules of social coexistence have disintegrated. In these cases, public discussion about socially innovative actions, strategies, practices and processes become particularly important, especially when the answers provided by public and private institutions are inadequate. The capabilities approach can be useful for redefining policies and practices that improve the lives of the most marginalised and powerless citizens in society (Chiappero-Martinetti, Houghton Budd, and Ziegler 2017; Ziegler, Karanja, and Dietsche 2013; Ziegler et al. 2017).

As I pointed out above, more recently the focus has moved from artefacts to innovation processes, and more specifically to the places where these take place: innovation systems, that is "*the network[s] of institutions in the public and private sectors whose activities and interactions initiate, import and diffuse new technologies*" (Freeman, 1987, p. 1). The relationship between the expansion of human capabilities and innovation processes is potentially virtuous: the expansion of the capabilities of individuals is not only instrumental to the growth of human capital, but it also affects individual agency, interpersonal relationships, relationships between groups, the creation of institutions and shared rules, the proper functioning of the democratic process. These changes create a fertile environment for the change and innovation of companies and innovation systems, as well as offering them a regulatory framework to choose "what innovation" to pursue. Innovation is not an objective and neutral process, but it depends on public financing and research choices, on the institutional context in which it is realised, on the learning processes and the interaction skills that are established. All of this can be strongly influenced by the expansion of individuals' capabilities and policies aiming to achieve this goal.

In this line of studies emerges a possible causal chain that feeds a virtuous (or vicious) circle between human development, innovation and economic growth. These three processes appear to be linked to each other by relationships of interdependence.

The relationship between human development and growth has been at the centre of interest since the very first UNDP reports (1990, 1996) indicated that *there is no close correlation between per capita income and human development*. Some countries showed that they could improve the well-being of their citizens regardless of the available material resources. But, as other studies highlighted, it was possible, *in the short run*, to record progress in human development despite limited or no economic growth, but *in the long run* human development must go hand in hand with a significant rate of growth (Ranis et al. 2000; Ranis and Stewart 2000; Boozer et al. 2003).

Starting with Solow's seminal contributions (1956, 1957), the link between innovation and growth is certainly the most studied of the three. Although the tradition of studies of the neoclassical mainstream tended to regard innovation as an essentially exogenous factor and freely available (Fagerberg, Mowery, and Nelson 2005), more recent studies point to a gap between countries with an ability to learn and those without. A crucial role in the relationship between innovation and growth is played by absorptive capacities. According to Cohen and Levinthal (1990), this can be defined as "the ability of a firm to recognise the value of new, external information, assimilate it and apply it to commercial ends" (128). Although it originally refers to single companies, this concept has also been used at a larger scale, for regions and countries. Developing countries can, through appropriate policies, build the innovation capacity needed to catch up. But there is also a relationship, especially for Keynesian scholars (Verdoorn 1949; Kaldor 1970), between growth and innovation. Income growth opens up new opportunities for the introduction of new products and processes, while a stagnant economy will hardly stimulate innovation.

The link between innovation and human development is certainly the least studied. As I noted earlier, the first studies, starting from (UNDP 2001) have highlighted that technological change is not limited to offering an indirect contribution to human development through economic growth and the greater resources available for social policies, but contributes directly to increase the set of capabilities that individuals can consider valuable. This happens in all fields, but especially in the health sector (vaccines and medicines), communications (which reduce isolation and allow better information and participation), agriculture (with increased production and price reduction), energy (alternative and less expensive sources) and manufacturing (which guarantees new and more solid opportunities for growth and employment). The relationship between human development and technology also flows in the opposite direction, as the former feeds the growth of human capital in terms of knowledge, creativity and participation. Better education contributes significantly to the creation and dissemination of technologies; more R & D scientists and more educated workers can use technologies more effectively; greater participation and social and political freedom create the conditions for more lively creativity.

The Proximity

Innovation cannot be fully understood without considering the central role of spatial proximity and the interaction between different agents in this process. A growing number of studies show that in an era of global competition when success increasingly depends on the ability to produce new and better products and processes, tacit knowledge (i.e. person-embodied knowledge, the diffusion of which is strongly influenced by distance and language) is the most important resource for the generation of innovation (Pavitt 2002). This is because the widespread availability of ICT's (Information and Communication Technologies) has rendered access to explicit/codified knowledge (in databases, blueprints, operating instructions, etc.) quite simple now. It follows that the creation of distinctive capabilities and competitive products increasingly depends on the production and use of tacit knowledge (Asheim and Gertler 2005; Asheim and Parrilli 2012).

Tacit knowledge is difficult to transfer over long distances because it is heavily dependent on the social and institutional context in which it is produced. Analysis that underlines the centrality of learning processes in activating change (Lundvall 1992; Lundvall and Johnson 1994) has shown how tacit knowledge is the result of complex social interaction. This interaction includes the flow of various types of knowledge between companies (i.e. clients, suppliers and competitors), research organisations (i.e. universities, public and private research centres) and public agencies (i.e. centres of technological transfer, development agencies, company incubators). The quality of interaction between these actors greatly (although not exclusively) depends on their ability to transfer non-codified knowledge through relationships based on proximity (Robertson, Jacobson, and Langlois 2009)

The concept of Regional Innovation Systems (RIS) is directly concerned with the processes and resources necessary for initiating and maintaining an innovation process (Pyka, Kudic, and Müller 2019; Capello and Lenzi 2021; Fernandes et al. 2021). RIS analysis is based on similar interpretations of the innovation phenomena but pays greater attention to their territorial dimension. Within this framework, "region" can be understood as a level of governance between the national level and the individual firm or cluster of firms. Regional governance can be in the hands of both private (individuals or associated firms, chambers of commerce and trade unions) and public actors (local governments, universities and development agencies). These actors are linked by relationships of exchange as well as by a certain degree of interdependency and share a "regional culture" based on sets of common attitudes, values, norms, routines and expectations. This regional culture, as we have seen, influences the way agents (individuals, firms and organisations) interact with each other in a given territory.

At the same time, individual capabilities are determined by social context and structures of living together, as well as by the trust and transparency governing relations among individuals, all factors that are strongly rooted at the territorial level.

According to Stewart and Deneulin (2002), in order to promote citizens' capabilities, we cannot focus exclusively on individual interactions, rather, it is also necessary to improve the structures of living together. Positive structures of living together improve individual well-being, enable individuals to be free agents, and encourage them to set valuable goals. "In other words, flourishing individuals generally need and depend on functional families, cooperative and high-trust societies, and social contexts which contribute to the development of individuals who choose 'valuable' capabilities" (68). Interest in the structures of living together is linked to the role they can play in influencing and shaping the skills of individuals. An important objective of development policies is thus to identify national and local interventions that lead to major changes in these structures of living together and limit the emergence of negative (dysfunctional) structures.

Virtuos/Vicious Circles

These contributions suggest that it is possible to identify links between human development, innovation processes and economic growth. Figure 1 illustrates six interactions, denominated by letters A to F, that will help me summarise the connections highlighted in our quick review. The diagram merely summarises some of the connections that emerged from the review and therefore cannot be either exhaustive or analytically comprehensive. Every relationship is a two-way relation, thus the type of relationship that is being discussed is distinguished by a directional arrow and the initials PP (Public Policy), IS (Innovation Systems), EG (Economic Growth) and HD (Human Development).

Let's see the individual relationships in detail. In doing so I will focus only on "endogenous" relations, i.e. those that link the three dimensions analysed: Human Development, Innovation and Economic Growth, leaving aside the exogenous impact of policies whose discussion would go beyond the aims of this paper (see Capriati 2018, Chapters 7–9).

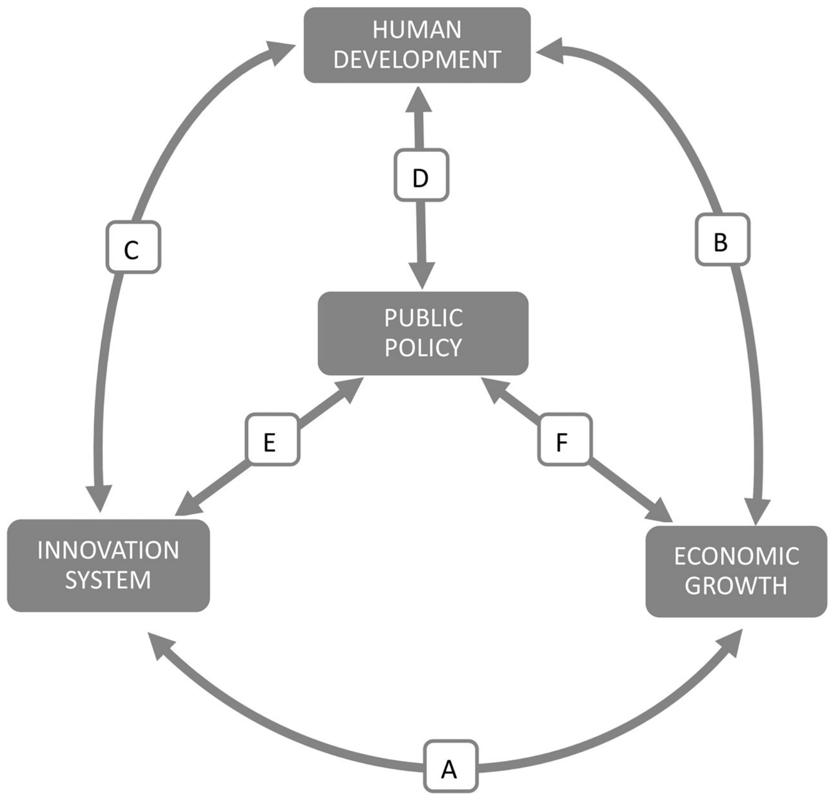


Figure 1. Connections between human development, economic growth, innovation systems and public policy.

A. IS→EG – virtuous *innovation systems* respond to the transformative pressures induced by the rapid change in science and technology, changes in markets and public choices. Good interaction between individuals, companies and institutions is a precondition for increased resilience of innovation systems and their *capability to innovate*. It translates into *innovation and technological change* that allows economic systems to meet needs and generate new resources. This feeds the process of *economic growth*.

EG→IS – Economic growth creates an environment conducive to economic and social change: new markets, economies of scale, new learning processes, new jobs and new skills. A stagnant economy can never stimulate innovation and social dynamism.

a. EG→HD – The process of *economic growth*, as mentioned several times in the sections above, is not an end but a mere means of development. The greater the income and the quantity of private goods and services, the more and better technologies extend the possibilities of individuals to live a life that they value. As it was emphasised above, however, the availability of these resources is not sufficient to ensure high levels of human development.

HD→EG – Human development is an end in itself. This does not entail that it has no direct and indirect effects on economic growth. An educated and healthy population has a direct effect on learning processes and economy's productivity; similarly, greater social cohesion and more trust between people foster the reduction of transaction costs, as well as improve the organisation and efficiency of enterprises and public administrations.

a. HD→IS – Human development has a direct effect on innovation systems, by improving individual, collective and institutional learning abilities. *Learning capabilities* benefit from the improvement of all individual capabilities: not just the capabilities that directly affect individual productivity (education, health), but also those that result from participation and social relations, from culture and greater awareness and ownership of community goals. The interactions between individuals in different positions, such as producers, users, workers, researchers, etc. benefit from a context in which inequalities (both income and non-income) are not exacerbated, where there are high levels of interpersonal trust and solid conditions for the rapid circulation of information and where common values and customs are shared. In addition, a cohesive and well-informed community exercises greater democratic control and contributes to greater transparency in public decisions on investments which affect research and innovation, and, more generally, in political decisions that affect innovation systems. A society with solid social safety nets stimulates enterprise and risk-taking.

IS→HD – Innovation systems help increase learning capabilities as well as technologies available to individuals and, in this way, expand their *capability set*. The actual impact on human development, however, will depend on *factors of individual conversions and the social context*.

In what follows, I will try to answer the following research questions: is there any evidence of the importance of these relations? Is there a circular relationship between innovation, human development and growth? To what extent does geographical proximity influence the interaction between these three dimensions?

I will start by describing (see Data set and Indexes section) the dataset employed; I will then explain the construction of the indexes used to summarise the dimensions of human development and innovation (I will measure growth through the most common indicators of national accounting). I will then illustrate indicator levels in European regions through maps and I will focus convergence processes (see Descriptive Analysis section). Finally, I will analyse the correlations between the summary indicators and test two econometric models (see Empirics section). The first is based on the data panel and it explores the simultaneous interrelationship between the variables, and the second estimates territorial spill overs.

Data set and Indexes

Following from Background section analysis, I focus on the regional dimension since this allows me to highlight the specificities of territorial innovation systems and local contexts that influence the capacities of individuals and groups. I have chosen to focus on European regions for two reasons. First, because in recent decades, thanks to specific guidelines of the Community Regional Policy, European regions have assumed an increasingly important role in the field of education, health and local development. Secondly, because focusing on European regions allows me to use a reasonably complete and homogeneous database.

The regional database includes data from 266 regions: all regions are within the 27 member states that formed the European Union in 2012 except for the four overseas territories of France. The source for the entire data set is Eurostat, and Table 1 lists the indicators used in the analysis. The reporting period covers the years 2000–2015.

The following analysis will be conducted using some summary indices developed from the merger of several partial indicators: Human Development Index (HDI) and the Innovation Capacity Index (ICI).

Table 1. List of data and sources used for panel.

	Data	Source
1	Total intramural R&D expenditure (GERD) by sectors of performance and NUTS 2 regions. UNIT: Percentage of GDP	EUROSTAT
2	Patent applications to the EPO by priority year and NUTS 2 regions. UNIT: Number	EUROSTAT
3	HRST by sub-groups and NUTS 2 regions. Persons with tertiary education (ISCED) and/or employed in science and technology. UNIT: Thousand	EUROSTAT
4	Population aged 25–64 with tertiary education attainment by sex and NUTS 2 regions. First and second stage of tertiary. Unit: PERCENTAGE education (levels 5 and 6)	EUROSTAT
5	Life expectancy by age, sex and NUTS 2 region. AGE: Less than 1 year	EUROSTAT
6	Population aged 25–64 with upper secondary or tertiary education attainment by sex and NUTS 2 regions. Upper secondary, post-secondary non-tertiary, first and second stage of tertiary education (levels 3-6)	EUROSTAT
7	Gross domestic product (GDP) at current market prices by NUTS 2 regions. Purchasing Power Standard per inhabitant	EUROSTAT
8	Young people neither in employment nor in education and training by sex and NUTS 2 regions. Percentage of people aged from 15 to 24 years.	EUROSTAT
9	Early leavers from education and training by sex and NUTS 2 regions. Percentage. AGE From 18 to 24 years. Population on 1 January	EUROSTAT
10	Population on 1 January by age, sex and NUTS 2 region. Unit: Thousand	EUROSTAT
11	Gross fixed capital formation by NUTS 2 regions. Million euro	EUROSTAT
12	Population aged 25–64 with tertiary education attainment by sex and NUTS 2 regions. UNIT: Percentage. ISCED11	EUROSTAT
13	Employment by sex, age and NUTS 2 regions (x 1000)	EUROSTAT

Human Development Index

The purpose of this indicator is to measure (however partially) the well-being of communities to complement the GDP indicator, based on three components: life expectancy, education and standard of living. For the European regions panel, the HDI is adapted due to unavailability of detailed data at the regional level.

The first component is measured by Life expectancy at birth, as a standard approach of calculation of HDI. For the second one, it is not possible to use the indicators that can be used nationwide for MYS mean years of schooling and EYS expected years of schooling, so I chose to measure the component Education by the percentage of population aged 25–64 with upper secondary or tertiary[1] education attainment. This appears to be the most useful proxy for measuring the level of formal education for the European regions, where the overall completion of the primary and secondary education has been achieved for some time.

For the control over resources the proxy indicator used in this case is the Gross domestic product (GDP) at current market prices at Purchasing power standard (PPS) per inhabitant. As income increases, the marginal contribution of one unit of income to the increase in capabilities of a person gradually decreases (Anand and Sen 2000). To take this characteristic into account, GDP per capita data are expressed in natural logarithms.

HDI is calculated in two steps. The first calculates a standardised index for each dimension based on the following relation:

$$\text{Dimension index} = \frac{\text{actual value} - \text{minimum value}}{\text{maximum value} - \text{minimum value}} \tag{1}$$

The maximum and minimum values (goalposts) are chosen to transform indicators expressed in different units into indices ranging between 0 and 1. To identify goalposts, I employed the maximum and minimum values of the period considered (2000–2015). This method was used in the first issues of HDRs, from inception until 1993.

After applying formula (1) to Education Index, to Life Expectancy and to the natural logarithm of real GDP per capita in PPS, to calculate the HDI it is necessary to compute the geometric mean of the three components.

$$\text{HDI} = (I^{\text{Health}} I^{\text{Education}} I^{\text{Income}})^{1/3}$$

To avoid false correlations when comparing indices, I employed a type of HDI that I name HDI* (that excludes the income component). Another benefit of this adaptation is that it allows me to isolate the "investment in people" component of the index and facilitates the comparison with levels and variations in per capita income.

Innovation Capacity Index

This index was developed adapting a methodology defined by Archibugi and Coco (2004), similar to that applied by UNDP in 2001 HDR. It is based on the three main components of technological capabilities:

A. creation of technology;
B. technological infrastructures and
C. development of human skills.

The Innovation Capacity Index at the regional level will only partially follow the technique used for its calculation at the national level, due to the lower availability of data, particularly for certain regions and for a sufficiently extended period of time (the study covers the period 2000–2015). The data will not include sub-indices related to technological infrastructure. Eurostat provides data on the use of internet and broadband but the earliest available information dates only to 2006 and, even so, the data are largely incomplete.

I, therefore, decided to limit the index calculation to two dimensions at the regional level i.e. to the creation of technology and the development of human skills.

For the first dimension, two indicators will be used: (a) number of patent applications at the EPO (European Patent Office) per one hundred thousand inhabitants and (b) R&D expenditure as a percentage of GDP.

For the second, the data from the two following sub-indices will be used:

a. *Human Resources in Science and Technology (HRST)* as a percentage of the labour force[2] that includes graduates and non-graduates who are engaged in scientific and technological activities; this information was considered an adequate way of covering human skills of the highest quality.
b. *the percentage of population aged 25–64 with completed upper secondary or tertiary[3] education,* this indicator has already been used to build the HDI at the regional level. It increases information on overall education, going beyond the purely scientific and technological activities that are measured by the previous indicator.

Also in this case, in the analyses that relate ICI and HDI, the first will be adapted by eliminating the component sub (b) in common with the second. In this case, the indicator will be named ICI *.

Income

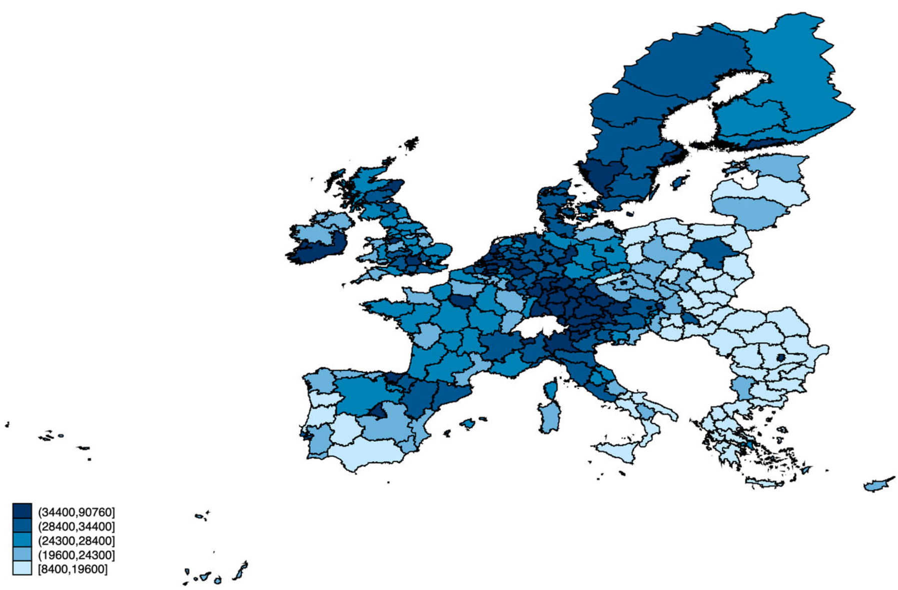
To measure income and material well-being at the regional level for our following elaboration will be used the Gross domestic product (GDP) at current market prices at Purchasing Power Standard per inhabitant.

Descriptive Analysis

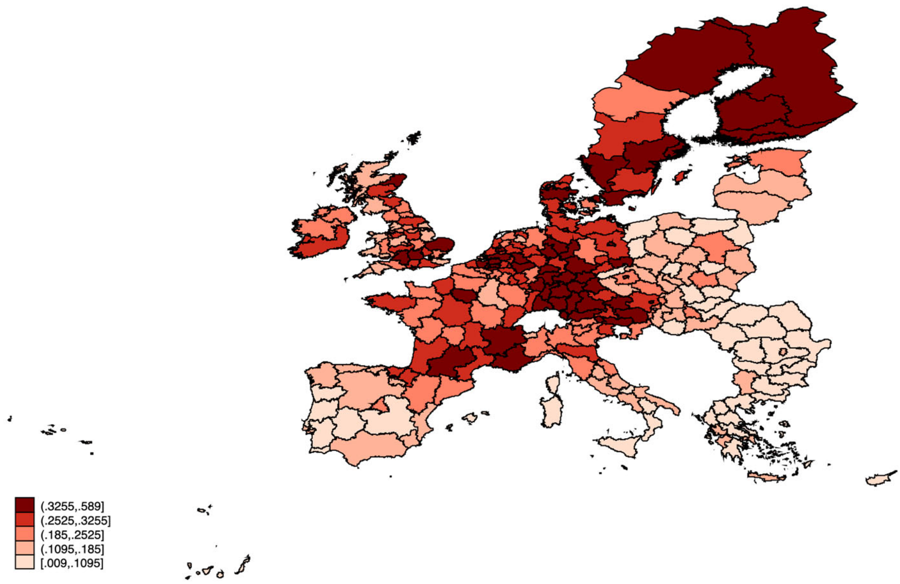
Level of Indices

It is not easy to show the value of a variable referring to 266 regions through a table. The use of maps helps me summarise the territorial differences of these three dimensions. I start from per capita income (graph 1). The map illustrating *the level of GDP per capita* (see Map 1) shows a concentration of high-income regions along an axis running from Austria to England, through the regions of Western Germany. This core extends to several regions in Northern Italy, Catalonia and the Basque regions of Spain, the southeastern parts of Ireland and Scandinavian countries. In general, there is a greater concentration of high income in regions that include country capitals or large metropolitan centres.

The *innovation* excellence map (see Map 2) in Europe extends from Zahodna in Slovenia to Austria, reaches the South of England through the regions in west-central Germany, Belgium and the Netherlands. This central axis has an important extension to the North-East, starting from Denmark and stretching to Finland, reaching across the South of Sweden with an important offshoot in France in the regions of Paris, Midi-Pyrenees and Rhone-Alpes. Around this central axis and its branches, are situated regions with medium to high levels of innovation capacity in Eastern Germany, North-Central Sweden, Estonia, the Czech Republic and most of the other regions in France and Great Britain. The area comprising this group of European regions leading in innovation is delimited on the East by the Baltic countries, Poland, Slovakia,



Map 1. Gross Domestic Product (GDP) at current market prices by NUTS 2 EU regions. Purchasing Power Standard per inhabitant (2015).



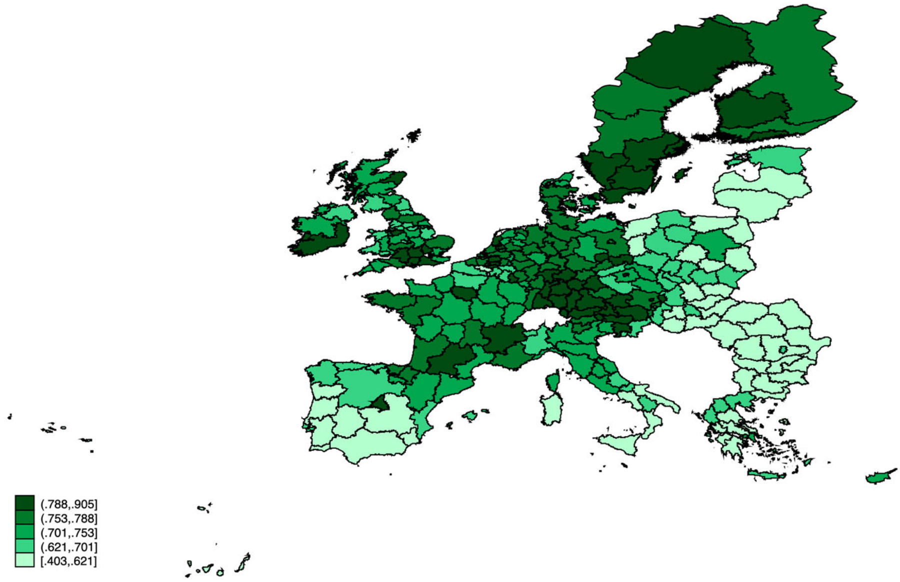
Map 2. Innovation Capacity Index by NUTS 2 EU regions (2015).

Hungary, Bulgaria and Romania, and on the South by Greece, Italy, Spain and Portugal.

Unlike the two previous maps, the one based on the *Human Development Index* (Map 3) shows relatively lower indices for North Italy and Est Germany; the higher rates are concentrated in southern regions of Germany, Sweden and France. Beyond the differences in details, the overall trend is confirmed: in the case of the Human Development Index, the leading regions are the central and northern parts of the continent ranging from Slovenia to England and extending to the Scandinavian regions, while eastern and southern regions result marginal.

Convergence

Do the three dimensions analysed for 266 regions tend to converge or to diverge over time? There is a vast literature that analyses convergence with regards to economic growth. Generally, to assess whether the gap between countries is shrinking or expanding over some time, I use computations which in practice show whether developing countries made more rapid progress than the developed ones. There are two main types of convergence (see Barro and Sala-i-Martin 1992): the *beta convergence*, i.e. a negative relation between income growth and its initial level (see e.g. Mankiw, Romer, and Weil 1992; Sala-i-Martin 1996; Evans and Karras 1997) and the *sigma convergence*, i.e. a reduced dispersion of the considered variable among countries with the progress of time (see, e.g. Young, Higgins M, and Levy 2008). The information obtained from calculating the standard deviation, the sigma convergence, in



Map 3. Human Development Index by NUTS 2 EU regions (2015).

my opinion appears to be more indicative. This measurement is not unduly affected by the initial level and allows me to follow the dispersion values year after year and track the underlying trends (see Figure 2).

First, looking at income: the index remains largely constant over the period considered, with a slight tendency to decrease until 2009, and an equally slight tendency to increase after that year. The highest variability is detected in the index of innovation. In the sixteen years included in the study, the innovation capacity index decreased from 0.7 to slightly more than 0.5 in 2015. The human development index too had a tendency to reduce during this period from 0.27 to 0.15 indicating, probably, the recovery of the most disadvantaged regions, particularly those in Eastern Europe. This index shows the lowest variability among the three.

Empirics

The descriptive analysis above presented some general insights on how different regions perform with respect to income, indices for innovation capacity, and human development. In this section, I will examine the mutually reinforcing relationships between these variables, based on the assumptions outlined in Data set and Indexes section. The first step in the analysis of the links between these three dimensions consists in performing a correlation analysis (see Correlation section). In the following section (Empirical Analysis: The Model and Econometric Strategy), I will apply two econometric models that will help me explore, in more detail, the relationship between the three

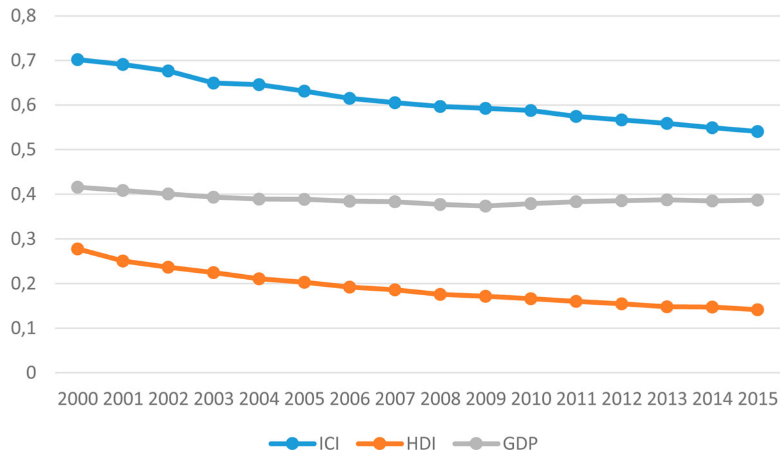


Figure 2. European regions. Sigma convergence test: coefficient of variation 2000–2015.

dimensions. This will allow me to examine the relationships in both directions, as highlighted in Figure 1.

Correlation

The results reported in Table 2 indicate the existence of reasonably strong (i.e. >0.5) and statistically significant correlation for all the main combinations tested. The correlation between human development and innovation* is 0.59, which confirms other recent empirical analyses (UNDP 2001; Ranis and Zhao 2013),. The correlation between innovation and average income also is also positive (0.60), again supporting the extensive literature on the relationship between these two dimensions. Finally, the relationship between human development* and income is also positive (0.57) which similarly confirms the empirical evidence on the relationship between growth and human development *in the long run*.

Empirical Analysis: The Model and Econometric Strategy

In this section, I will explore in depth the mutually reinforcing relationships between income, innovation, and human development, using Figure 1 as an underlying framework. I will focus on the *endogenous* relationships, i.e. relations involving only innovation, growth and human development – ignoring the *exogenous* impact of policies on each of these relationships. I will attempt to answer the following questions: is there a circular relationship between innovation, human development, and growth? To what extent does geographical proximity influence the interaction between these three dimensions? I will do so using two approaches. The first aims to test whether these dimensions are linked by a circular relationship through which they simultaneously affect each other; to do that, I will use the regional data to apply an

Table 2. Matrix of correlation.

Variables	Income	Innovation*	Innovation	Human Development*	Human Development	Poverty	School Leave	Gender Equality	Fixed Investments
Income	1.0000								
Innovation*	0.5120	1.0000							
Innovation	0.5985	0.9577	1.0000						
Human Development*	0.5661	0.5462	0.6989	1.0000					
Human Development	0.7455	0.5905	0.7347	0.9576	1.0000				
Poverty	−0.3229	−0.3566	−0.4142	−0.3568	−0.4029	1.0000			
School Leave	−0.1302	−0.2464	−0.3726	−0.6065	−0.4837	0.3778	1.0000		
Gender Equality	0.1837	0.3312	0.4384	0.4310	0.3537	−0.3382	−0.4600	1.0000	
Fixed Investments	−0.2057	−0.2719	−0.3079	−0.3021	−0.2675	−0.0272	0.2140	−0.2672	1.0000

Note: All correlations are significant at the 1% level.

econometric model that allows me to measure the intensity and significance of the mutually reinforcing relationships between these dimensions. The second approach focuses on the spatial dimension of the relationship between income, innovation, and human development, and analyses regional data through spatial econometric methods.

The Panel Analysis

The model used to investigate the virtuous/vicious circle of income, innovation and human development is specified as follows:

$$
\begin{aligned}
y_{it}^{1} &= \alpha^{1} y_{it-2}^{2} + \beta^{1} y_{it-2}^{3} + \gamma^{1} x'_{it-2} + \varepsilon_{it}^{1} \\
y_{it}^{2} &= \alpha^{2} y_{it-2}^{1} + \beta^{2} y_{it-2}^{3} + \theta^{2} x'_{it-2} + \varepsilon_{it}^{2} \\
y_{it}^{3} &= \alpha^{3} y_{it-2}^{1} + \beta^{3} y_{it-2}^{2} + \delta^{3} x'_{it-2} + \varepsilon_{it}^{3}
\end{aligned}
$$

where $i=1, \ldots, 266$ denotes regions, y_{it}^{1}, y_{it}^{2}, y_{it}^{3} are the dependent variables corresponding respectively to *Income*, *Innovation* and *Human Development*, x' stands for the set of explanatory variables and ε_{it}^{1}, ε_{it}^{2}, ε_{it}^{3}. are the error terms.

In the first equation, lagged employment (employed over total population aged 15-64) and fixed capital investments over GDP are included as main regressors. In the second equation, lagged employment, fixed capital investments and gender equality (approximated by the ratio between man and women's employment rates) are also included as controls. The only macro variable included is the ratio between investment and GDP. The aim is to measure how investment affects growth and innovation processes; in particular, we are interested in investigating the effect that technological change occurring as part of investments has on broader innovation processes. In the third equation, I include lagged income, innovation, and gender equality. Country dummies are also included in all the three equations. In order to reduce potential problems with circular causality and high correlation between variables, the human development index employed here is computed excluding the income dimension; likewise, innovation is calculated without education (see Descriptive Analysis section).

The system in (1) has been solved using the "three-stage least squares" (3SLS) method (Zellner and Theil 1962). I judge this to be the most appropriate method for this analysis, as it makes it easy to compare coefficients across regressions. It also allows me to estimate systems of equations containing endogenous variables among the regressors, which are also dependent variables in other equations in the system. All the dependent variables are explicitly taken to be endogenous to the system; all other variables are instead treated as exogenous to the system, and thus used as instruments for the endogenous variables. This strategy allows me to highlight feedback loops and simultaneous relations between the variables of interest.

The Spatial Analysis

Since the spatial dimension is also relevant in determining the evolution of the circular relationships under study, a spatial approach has been also considered to account for potential spatial dependence, namely for the fact that income, innovation and human development values are likely to be dependent across units of observations due to spatial effects. This model allows me to take into account the influence that income, innovation and human development achievements for a given region i can have on the values of the same variables in adjacent regions. Hence, the second specification tested is as follows:

$$y = \rho Wy + \beta X + \varepsilon$$

where y denotes the vector of the dependent variable (i.e. Income, Innovation or Human development, respectively), ρ is the spatial autoregressive parameter, W is the spatial weight matrix, β is the vector of the coefficients, X is a matrix standing for all the regressors included, and ε is the vector of normally distributed, homoscedastic and uncorrelated errors (LaSage and Pace 2009).

All the variables employed are defined in log form and controls are included in X: school leavers (percentage of the population aged between 18 and 24 years who are early leavers from education and training), NEET (young people not in employment, education or training), gender equality and accumulation rate. In case of the first variable, with some stretch, we can consider the drop out from formal education as a symptom of disadvantage and poor social cohesion, and therefore as a proxy for social capital in the region. The second variable (NEET) includes the percentage of the population aged between 15 and 24 years who are neither in employment nor in education and training. This indicator can be considered a good proxy of the effectiveness of the training system and of labour policies. The spatial weighting matrix (W), which synthetises the structure of spatial dependence, is a 266 by 266 matrix, where each entry is a measure of the spatial influence or spatial proximity between regions i and j. This analysis has been based on the centroids distances[4] between each pair of spatial units, computed using the longitude and latitude coordinates for each region at NUTS-2 level.[5] The neighbours for a given observation are identified using the k-nearest neighbours criterion. According to this procedure, the five nearest neighbours of each spatial unit are weighted by their inverse distance i/d_{ij}, where d_{ij} is the distance (expressed in kilometres) between regions i and j (for $j \neq i$): this implies that larger values of W^{n5} indicate that the regions are closer, and all but the five nearest neighbours receive weight equal to zero.

As for the estimation method, the approach based on Maximum Likelihood (ML) has been followed to get consistent estimates of the spatial parameter ρ (see Lee and Yu 2010; Elhorst, Piras, and Arbia 2010).

Empirical Analysis: The Results

The Panel Analysis

Table 3 below reports the results from the 3SLS estimation (specification 1) with a 2-year lag of the regressors.[6] The results clearly show a virtuous circle between income, innovation, and human development. The coefficients of the relationships are positive and significant. Taking a closer look, we can observe that in regression (2) the coefficient describing the relationship between GDP and innovation is greater than 1: a 10% increase in income per person increases innovation by 16%. In the same regression, human development has a strong mutually reinforcing relationship with innovation (a 10% increase in HDI* causes a 12% increase in innovation) and a positive (albeit weaker) mutually reinforcing relationship with income. The coefficient that links innovation to human development is very small, even if it is still significant (see regression 3). A 10% increase in innovation causes only a 1% change in the Human Development Index. This may be the consequence of the multidimensionality of the human development index (which in the chosen specification includes only life expectancy and education) and of the specificity of the index chosen to measure innovative capacity (which includes expenditure on R&D and patents). The relationship likely capture the fact that R&D and patents have a positive, yet indirect and longer term, effect on life expectancy and education. All in all, the analysis supports the hypothesis that virtuous circles occur between the three central dimensions though with different coefficients and degrees of intensity.

Let us also examine the impact of control variables on growth, innovation and human development. Looking at income as the dependent variable (regression 1), employment rate and investments on GDP have the expected positive signs. A 10% increase in investment causes a 1.4% increase in the

Table 3. Three-stage least squares (3SLS) estimation results (2 years lag).

Variables (all in log)	Income	Innovation	Human development
Income		1.5977***	0.1889***
		(0.0393)	(0.0111)
Innovation	0.2616***		0.0951***
	(0.0062)		(0.0046)
Human development	0.2899***	1.1951***	
	(0.0233)	(0.0572)	
Gender equality		0.2714***	0.2153***
		(0.0993)	(0.0238)
Employment	0.2475***	0.2316*	
	(0.0449)	(0.1283)	
Fixed investments/GDP	0.1422***	−0.4060***	
	(0.0218)	(0.0524)	
Constant	9.3848***	−17.7050***	−1.9914***
	(0.2010)	(0.4992)	(0.1187)
Observations	2,660	2,660	2,660
R-squared	0.561	0.601	0.479

Standard errors in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

GDP growth rate, while a 10% increase in employment causes a 2.5% increase in growth rate.

I find innovation is favoured by both a fairer employment of women and a high total employment rate (regression 2). The only variable in the regression with an unexpected sign is the investment rate. A 10% increase in capital accumulation causes a reduction of about 5% in the capacity for innovation. A possible explanation may be that in recent years innovation has not taken the form of technology affecting invested capital, but has rather increasingly concerned products, materials, knowledge, organisation of production and logistics.

Finally, human development (regression 3) is, as expected, positively influenced by a high ratio between female and male employment rates.

The Spatial Analysis

Table 4 shows the coefficients estimates obtained by testing the SAR model, which considers spatial effects between regions by including the adopted weighting scheme (W^{5n}). Note that country fixed effects are included in these estimations; moreover, to account for possible endogeneity due to circular causality, income, innovation, human development and fixed investment variables have been lagged by one period.

As shown in Table 4, coefficients estimated using this method are mostly statistically significant and have the expected sign. Moreover, there is clear evidence of regional spatial spill-overs (measured by the Spatial lag parameter).

Elaborating further: once spatial dependence among units in the dependent variable is taken into account, mutual causal linkages between income, innovation and human development achievements appear clearly, consistently with previous results. The parameter estimates of the control variables mostly show the expected sign and a highly significant influence on the dependent variable of interest. It is worth underlining that results for the spatial lag parameter display a highly significant (at 1% level) and positive spatial dependence in all specifications. The very large magnitude of the coefficients associated with income and human development (ranging between 0.91 and 6.79) confirms the presence of strong positive interaction effects based on geographical proximity (i.e. spatial spill overs) among the observed regional units. On the contrary, the parameter of innovation spatial dependence, albeit positive, is very low (0.39 and 0.10). This result indicates a lower tendency of innovation processes to propagate territorially and supports path dependence analysis and the idiosyncrasy of such processes.

Final Considerations

The analysis of empirical relationships conducted so far has essentially confirmed the theoretical argument of the two initial sections allowing me to

Table 4. SAR (with spatial fixed effects), ML results.

Explanatory variables	Dependent variables					
	Income		Innovation		Human development	
Income (first lag)			0.8836*** (0.2148)		0.4709*** (0.0275)	
Innovation (first lag)		0.0182*** (0.0055)				0.0191*** (0.0068)
Human Development (first lag)	0.0368** (0.0145)			0.0483*** (0.0182)		
School leave	−0.1431*** (0.0205)	−0.1495*** (0.0206)	−0.1403*** (0.0464)	−0.3305*** (0.0862)	−0.1285*** (0.0214)	−0.1506*** (0.0186)
Neet	−0.0034** (0.0017)	−0.0038** (0.0017)	−0.0108 (0.0075)	−0.0168* (0.0087)	−0.0030** (0.0012)	−0.0045*** (0.0012)
Gender Equality	0.1794*** (0.0614)	0.1920*** (0.0625)	0.3322* (0.1911)	0.5128*** (0.1170)	0.5365*** (0.0984)	0.3590*** (0.0839)
Fixed investments (first lag)	0.1399*** (0.0240)	0.1347*** (0.0240)		0.0061 (0.1100)		
Spatial lag parameter	6.746486** * (1391183)	6.766815*** (1367986)	0.1074761*** (0.0828075)	0.3856869*** (0.1957373)	1.081158*** (0.1260829)	6.20867*** (1.502524)
Observations	3,990	3,990	3,990	3,990	3,990	3,990
R-sq within	0.2215	0.2108	0.0459	0.0219	0.6463	0.3515
Number of id	266	266	266	266	266	266

Standard errors in parentheses: ****p* < 0.01, ***p* < 0.05, **p* < 0.10.*

answer the questions posed at the beginning of this article. First, the estimations indicate that there is a mutually reinforcing relationship between human development, innovation and economic growth. The relationships between human development and innovation, and between income and innovation are especially strong. Greater gender equality appears to promote the growth of people's capabilities and innovation capacities.

Second, the regional analysis has further confirmed the existence of virtuous circles and highlighted the presence of spatial links that affect the three relationships. In particular, changes in the three variables analysed are all influenced by changes in the same variables in neighbouring regions: the income (innovation, human development) growth of a region is influenced by the income (innovation, human development) growth of surrounding regions. This influence appears weaker for the processes of innovation than for growth and human development. Overall, the analysis confirms the importance of geographic proximity in the evolution of the three processes.

The descriptive analysis of the data provides additional insights. Human development in European regions, as represented by HDI, appears to follow a long-term trend of convergence. The differences between regions are much smaller compared to the other two indices and decrease progressively. Differences in per capita income are still high and, within the timeframe of the study, did not show any clear decreasing trend. On the contrary, after 2009, they tend to increase. Regions with the highest income are concentrated in Northern and Central Europe. Innovation excellence is concentrated mainly in the central and northern regions of the continent, with southern and eastern regions lagging behind.

These results have of course important implications for development policies. It seems clear that all variables need to be promoted simultaneously and can have positive effects on each other. Though I am unable to elaborate on this here, due to lack of space I want to highlight two points: the importance of setting human development as the ultimate goal of innovation policy human development, and the need to formulate macroeconomic policies fostering innovation and human development.

The capabilities approach offers a wide range of tools for evaluating innovations. Everything revolves around fundamental questions like: *Which* capabilities? *Whose* capabilities? *How* are these capabilities promoted? The answers to these questions cannot be answered without input from the people who are directly or indirectly interested in the changes brought about by innovation. Their liberties come before innovation and the latter must respond as much as possible to the need to expand the former (Drèze and Sen 2002). Choices pertaining to innovation policy are currently almost exclusively made by technical and economic elites. However, goals do not always coincide with those of the individuals and groups most affected by these choices (Frey 2019). To ensure innovation policy effectively promotes its ultimate goals, it is essential to bring the citizens' voices at the front of innovation policymaking.

The second implication concerns macroeconomic policies for innovation and human development. Employment is central to the expansion of individuals' freedoms and to the processes of innovation. Indeed, adequate wages and learning processes, collaborative ways of organising work and innovation, social recognition and personal gratification are inter-linked phenomena (Capriati and Divella 2020). A labour market that is precarious and unbalanced in favour of the entrepreneur, with few unions, with considerable freedom of dismissal and low wages, will hardly generate the learning processes and organisational structures needed to foster innovation. Underpaid workers and unmotivated employees will not feel gratified. This will reduce the opportunities to interact in innovation systems and will inhibit the proper functioning of institutions. Policies aimed at stabilising the economic cycle and reaching full employment, more labour-friendly employment policies, and social policies that reduce the risk of job insecurity and social exclusion are at the same time a contribution to the expansion of people's capabilities and a boost towards a more innovative and fairer economy.

Disclosure Statement

No potential conflict of interest was reported by the author.

Notes

1. Upper secondary, post-secondary non-tertiary, first and second stage of tertiary education (levels 3–6).
2. Persons with tertiary education (ISCED) and/or employed in science and technology. Human Resources in Science and Technology (HRST) are people who fulfil one or other of the following conditions:
   - successfully completed education at the third level in an S&T field of study,
   - not formally qualified as above but employed in an S&T occupation where the above qualifications are normally required.
3. Upper secondary, post-secondary non-tertiary, first and second stage of tertiary education (levels 3–6)
4. The word "centroid" in the literature on geographic information systems indicates a weighted average of the vertices of a polygon that approximates the centre of the polygon (see Waller and Gotway 2004, 44–45).
5. These are provided by the dataset "Nomenclature of Territorial Units for Statistics (NUTS) 2010 – European Commission, Eurostat/GISCO", which represents the regions for levels 1, 2 and 3 of the Nomenclature of Territorial Units for Statistics (NUTS) for 2010.
6. Regressions were also made with delays of 3 and 5 years which overall confirmed the results obtained.

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