Regional Human Capital and University Orientation: A case study on Spain

Mabel Sánchez-Barrioluengo[1]

Davide Consoli

INGENIO (CSIC-UPV), Valencia (Spain)

> PLEASE DO NOT QUOTE WITHOUT AUTHORS´EXPLICIT PERMISSION <

Abstract:

This paper analyzes the determinants of local human capital (HC) endowment by means of an empirical study on Spanish regions. It represents a contribution at the interface of two consolidated areas of research. On the one hand, the literature on economic geography that articulates in great detail the effect of local characteristics on the performance of a regional economy. With respect to this, we argue that the traditional measures of HC in these studies mostly focus on the supply-side (i.e. total number of graduates) but neglect the dynamics of local labour markets. On the other hand the labour economics literature proposes a more nuanced approach based on the study of changes in the relative demand of workers' skill. Here, we argue, this more direct measure of labour market dynamics is rarely used to capture the specificities of the attendant regional context. We bring together these two strands of literature to analyse the interplay between demand and supply of skills across 17 regions in Spain. Our analysis captures the effect of regional factor bias by using a novel indicator of university orientation through mission engagement as well as various local techno-economic characteristics. The main finding is that university orientation bears a differential effect on local labour markets. Accordingly we identify three groups: research-oriented regions (leaders); industry intensive regions (followers) and a group of backward regions (laggards) to capture differences in terms of underlying factors influencing skill patterns change.

Keywords: Human Capital; University Orientation; Skills; Region

[1] Corresponding author: msbarrioluengo@ingenio.upv.es

1 Introduction

The role of Higher Education Institutions (HEIs) in regional economic development is an issue of debate among both scholars and policy-makers. From the perspective of economic geography, human capital (HC) is a key source of innovation, economic growth and regional competitiveness (Glaeser *et al.*, 1995; Glaeser, 2005; Uyarra, 2010; Goddard *et al.*, 2012). Although universities are portrayed in this literature as key hubs for the generation and circulation of high-skilled workers (Florida *et al.*, 2008; Abel and Deitz, 2012), no clear arguments are offered with regards to persistent differences in the ability to generate and use knowledge across regions. On another front, studies on the economics of university articulate in great detail the historical determinants of higher education and the changing relation of the latter with the attendant societal context (Wittrock, 1993; Geuna, 1999; Youtie and Shapira, 2008). The contribution of HEIs is conceptualized here as flowing through three main channels coinciding with the apocryphal “missions”, namely (and concisely): the provision of teaching and training; scientific research; and the promotion of university-society synergies. This approach offers a somewhat richer characterization of HEIs’ activities but, arguably, overlooks the dynamics that influence demand for skills at regional level. On the whole we observe that the foretold traditions strive to emphasize different aspects of the same phenomenon rather than being in opposition with one another, and indeed they share common ground. First, both streams portray universities as strategic hubs entertaining a wide spectrum of formal and informal relations with various other actors within their regions. Secondly, both approaches concur in understanding HEIs as a knowledge-creating entity and in acknowledging the sheer diversity of forms of knowledge and of pathways though which this can be put to use.

Our claim is that the gaps identified above have a common root, namely the lack of operationalization of key concepts such as Human Capital and University Mission which are treated, at best, only in abstract terms. The present paper seeks to analyze the relationship between of HEIs´ mission orientation and HC endowment of their regions. To do so we elaborate, first, a critical assessment of consolidated notions in the literature. We argue that since the opportunities and the challenges at play in different regional contexts have a strong effect on the development of individual HEIs, the prototypical "one-size-fits-all" approach to university mission falls short. Is it realistic, or even desirable, that all universities are expected to engage all missions at once (Sánchez-Barrioluengo, forthcoming)? Subsequently, we suggest that regional factor bias may trigger selection effects on mission engagement, and that the extent of this relation has not been analyzed in great depth so far. Our conjecture is that prolonged commitment towards a particular university mission, or inertia, can be either a catalyzer or a barrier for the pursuit of innovation opportunities. Conversely, local labor markets may or may not match the orientation of the regional HEIs under the influence of cyclical or technological forces (Beaudry *et al.*, 2010; Autor and Dorn, 2013). On the whole we argue that previous work on regional economic development has disregarded the complementarity (or lack of thereof) between regional specialization, factor endowment and traditional indicators of employment dynamics such as skill intensity and wages.

This paper seeks to tackle this gap by focusing on three questions:

- What is the composition and dynamics of regional human capital?
- What are the determinants of these dynamics?
- Does university orientation affect the evolution of regional human capital?

We explore these issues by means of an empirical study on 17 regions and 47 public universities in Spain over the period 2003-2010. Addressing the foretold questions will entail the elaboration of novel empirical constructs and their operationalization in two steps. First, assuming that missions are meaningful constructs to capture university orientation and that available indicators of current activities are adequate to systematize these strategies, we use data on 20 performance indicators (i.e. total enrolled students, research and third stream funding, scientific production, knowledge-exchange activities) to build an index of *regional university orientation*. Through the latter we measure individual university performance in each of the three "missions". This novel index captures in a synthetic way the relative importance of university engagement by assigning key HEIs activities to a particular mission construct. Secondly, building on recent research in the area of labor economics we compute an index of *regional skill intensity* that captures both quantitative and qualitative features of local human capital (see e.g. Spitz - Oener, 2006; Goos and Manning, 2007; Autor and Dorn, 2013). This second index is built by merging employment data from the Spanish Labor Force

Survey (1-digit occupations and sectors[2]) with data on the skill content of occupations for USA (source: O-NET).

Two important contributions stem from this work. On the one hand, our analysis adds to the literature of economic geography by offering a measurement of HC based on the specific task content of occupations. This index is a step forward towards the widely debated need for better indicators of human capital that goes beyond traditional 'white-collar vs. blue-collar' characterizations of the labor force. A direct, albeit surely imperfect, measure of the skill content of occupations is a revealing indicator of how qualitatively different forms of know-how coalesce within an occupation. As such, it is a more comprehensive measure of the cognitive input to labor productivity. On the other hand, this study elucidates important aspects of the relation between demand and supply of knowledge as mediated by institutional processes like education and labor markets. The paper is then structured as follows: Section 2 presents a literature review on the role of HEIs in regional development and economic growth. Subsequently, we present a synthesis of scholarly works on skills endowment and labor markets. Section 3 offers a summary of the empirical strategy, the data sources and of the methodology for the analysis that is carried out in Section 4. Section 5 concludes and summarizes.

2 Literature review

2.1 Human capital: the backbone of the knowledge economy

Human capital (HC) is widely been regarded as one of the key inputs for economic growth, especially in the context of modern knowledge economies. Societies with 'better' HC are expected to enjoy greater development potential compared to societies with scarce or inadequate human resources (Rodríguez-Pose and Vilalta-Bufí, 2005). At the macro-economic level, the importance of HC has been highlighted in various forms. The area of economic geography studies highlights its primacy for innovation, economic and employment growth, income levels and competitiveness (Barro, 1991;

[2] Sectors are grouped following the Spanish Classification of Economic Activities (CNAE) equivalent to Standard Industrial Classification (SIC): (A) Agriculture, forestry and fishing; (B) Mining; (C) Construction; (D) Manufacturing; (E) Transportation, Communications, Electric, Gas, and Sanitary Services; (F) Wholesale Trade; (G) Retail Trade; (H) Finance, Insurance and Real Estate; (I) Services; (J) Public Administrations.

Barro and Lee, 1994; Glaeser *et al.*, 1995; Glaeser, 2005; Florida *et al.*, 2008). While seminal works focus on national economies as a whole, more recent studies take into account the heterogeneity that exists at lower levels of aggregation (Berry and Glaeser, 2005) arguing that HC is a good predictor of economic vitality in a region (Abel and Deitz, 2012). In the traditional scheme, university spillovers are the engine of prosperity and operate in a complementary fashion: HC facilitates the generation and circulation of novel ideas (Romer, 1990; Moretti, 2004); R&D activities permit the exploration and the transfer of new knowledge, both crucial for innovation; and universities magnify the benefits of proximity (Wallsten, 2001) thus contributing to the local environment by facilitating the creation of new business or attracting firms (Anselin *et al.*, 1997). In fact, spillovers alter the composition of local labor markets by increasing the demand for specialized skills and by attracting business in search of HC (Audretsch *et al.*, 2005). As a consequence, firms located in areas with high levels of HC carry a competitive advantage rather than letting suppliers' and customers' geography alone dictate their location (Glaeser, 2000). These findings are corroborated by the observation that HC increases individual-level productivity and idea generation (Becker, 1964, cited in Abel and Deitz, 2012).

However, according to Florida *et al.* (2008), the debate boils down to two key issues: first, how can HC be measured most reliably? And, second, though education outcomes are established indicators of talent-related potential, the workings of local labor markets play a role in how skills availability translates into tangible economic benefits. Traditionally, HC has been considered as a function of basic inputs such as education and training, and the most conventional measure along this logic is the local ratio of graduates (such as bachelor's degree or higher levels). We argue, however, that this is an incomplete indicator in that it disregards the heterogeneity of forms of know-how involved in actual labor market dynamics. This paper offers an alternative approach to study the connection between demand and supply of knowledge as mediated by institutional processes such as education, employment and economic performance.

2.2 Universities as human capital and knowledge producers

Universities and HEIs are prime sources of new HC and their structural and functional transformations of HEIs over the last three decades have modified their role as contributors to economic growth (OECD, 2004). Traditional missions, such as teaching and research, are now seen as part of a broader ranging and more complex nexus of (non-strictly) market-oriented and knowledge transfer activities (Louis *et al.*, 1989; Klofsten and Jones-Evans, 2000), that includes 'soft' activities (advisory roles, consultancy, industry training, production of highly qualified graduates), closer to the traditional academic paradigm, as well as 'hard' activities such as patenting, licensing and spin-off activities (Philpott *et al.*, 2011). Their contribution to the local surroundings is often conflated with their capacity to provide skilled workers to local labor markets (Abel and Deitz, 2012). Benneworth (2005) describes these institutions as 'knowledge generator subsystems' living inside a virtuous circle of global knowledge flowing through the region and out into global markets that create beneficial spillovers for local firms (business are the 'knowledge utilizer subsystem') while at the same time attracting external investors.

We conceptualize here the contribution of HEIs as flowing through three main channels, or the apocryphal "missions", namely (and concisely): the provision of teaching and training; scientific research; and the promotion of university-society synergies. In other words, universities develop strategic priorities and seek to balance teaching, research and interaction with socioeconomic environment (ISEE) to contribute to the achievement of national, regional and local goals; to create skilled human capital; and to produce and transfer know-how (Drucker and Goldstein, 2007). Understanding university's missions as their main strategies to contribute to society, three main objectives are derived. Teaching is aimed at the creation of HC in the form of higher skilled labor (OECD, 2008). The second and the third missions include a specific knowledge component. The purpose of research is the production of knowledge and, because a huge part of this knowledge is tacit, embodied in individuals, rather than being easily codified and transferred (Arbo and Benneworth, 2007), third mission goal is mainly knowledge transfer. These strategies are in accordance with the view, by local and regional authorities, of universities as providers of knowledge and skills (Goddard and Chatterton, 1999) to stimulate technical innovation and promote higher productivity and positive externalities in the form of knowledge spillovers to the private sector (Anselin *et al.*, 1997). However, this current model of universities as centers of excellence in education, research and third mission (that is, interaction with local socioeconomic actors) is perceived to be out of synch with current societal needs and therefore in urgent need of reform (EC, 2006). At the core of this wave of revisionism is the recognition of the shortcomings of the "one-size-fits-all" university model: this approach overlooks, on the one hand, the complex nature of the university *qua* institution (Olsen, 2007) and the many tensions which arise in the process of engagement (Pinheiro *et al.*, 2012), as well as, we argue, the dynamics that influence demand for skills at regional level. One of the explanations of these differences lies in the historical different functions, resources, networks and spatial aspirations within diversifying national higher education systems (Teichler, 1988; Martin, 2003; Teichler, 2004). As a result, universities present different capacities and abilities to engage and contribute to society. For example Hewitt-Dundas (2012) found that in the UK, universities' approach to knowledge transfer was mainly shaped by research quality whereas low research intensive universities may be more effective in HC development through courses for business and the community. In these terms, Florida *et al.* (2008) argue that research universities has been found to be a key factor in both the production and distribution of HC.

Given the importance of HC to the economic performance of regional economies, increasing population and employment growth, wages, income, innovation and economic growth (see e.g. Barro, 1991; Barro and Lee, 1994; Glaeser *et al.*, 1995; Glaeser, 2005; Florida *et al.*, 2008), there is surprisingly little research on the factors that drive differences in HC accumulation across geographical areas (Abel and Deitz, 2012). The objective of this article is to shed light on this issue by analyzing the determinants of HC endowment in regional labour markets. Coherent with the framework outlined so far, HEIs´ mission orientation is expected to play a key role by virtue of its broad spectrum of knowledge-generating activities.

2.3 Measuring knowledge through skills endowment

One of the purposes of this paper is to highlight that economic activities are bundles of tasks whose execution entails the generation and/or application of specific knowledge (Nelson and Winter, 1982). Skills are individual abilities or proficiency in carrying out such activities, and occupations are industry-specific pathways for matching skills with institutionally agreed tasks.[3] Therefore job specifications are blueprints – imperfect as

[3] To fix ideas, some skills are generic and can be applied to a broad range of tasks while others are specific to particular tasks; some skills are used to generate cognitive responses, others involve physical activities; finally, some skills pertain to the individual's sphere while others facilitate interpersonal interaction.

they may be – of the repertoire of skills that the labor force is expected to possess and use in order to carry out successfully particular work tasks (Autor *et al.*, 2003; Levy and Murnane, 2004). In aggregate, the composition of the workforce reflects the knowledge mix that is relevant in a particular context – i.e. industrial sector or geographical region – at a specific moment. By the same token, as industry or regional needs change, occupations evolve and so do the agreed tasks and the relevant skill mix. This implies that the complementarities across different forms of knowledge matter a great deal for the ability of an individual worker to meet successfully their job requirements depends on the composition of the overall employment structure and on mechanisms of intra-occupations collaboration (Rosenberg, 1976). In turn, the emergence of novel configurations in the skill mix reflects changing styles of framing and addressing job tasks by redistributing responsibilities across professional groups (Sabel, 1982).

To operationalize these ideas, the intensity of use of a task is a direct measure of the demand for the skill that is needed to perform a specific work activity (Autor *et al.*, 2003; Levy and Murnane, 2004). Breaking down productive activities into functionally different task groups moves beyond traditional categorizations, such as high-skilled or low-skilled workers, and opens up new possibilities for understanding how individual abilities shape innovation and competitiveness. The 'task-based approach' proposed by Autor (2013) carries important methodological advantages, most of all the possibility of elaborating direct measures of which forms of know-how translates into labor output. Taking the cue from this, we argue that (i) occupational characteristics are a better indicator of how knowledge is converted into work activities, and (ii) skill intensity are a direct empirical measure of supply and demand forces filtered by the reality of the local labor markets. This conceptual proposition opens the way to an analysis of the differences across regions.

3 Empirical Strategy

This section describes our empirical strategy based on three assumptions: first, at institutional level, university missions can be understood as constructs that reflect university strategies, and that tangible university activities measured by performance indicators are an adequate materialization to systematize these strategies[4]; second, regional HC's knowledge can be measured trough the intensity of use of a task because it is a proxy of the demand for the skill needed to perform a specific work activity (Autor *et al.*, 2003; Levy and Murnane, 2004); and third, relating both concepts, missions can be treated as an input in terms of skill performance to analyze the impact of university orientation in regional HC endowment.

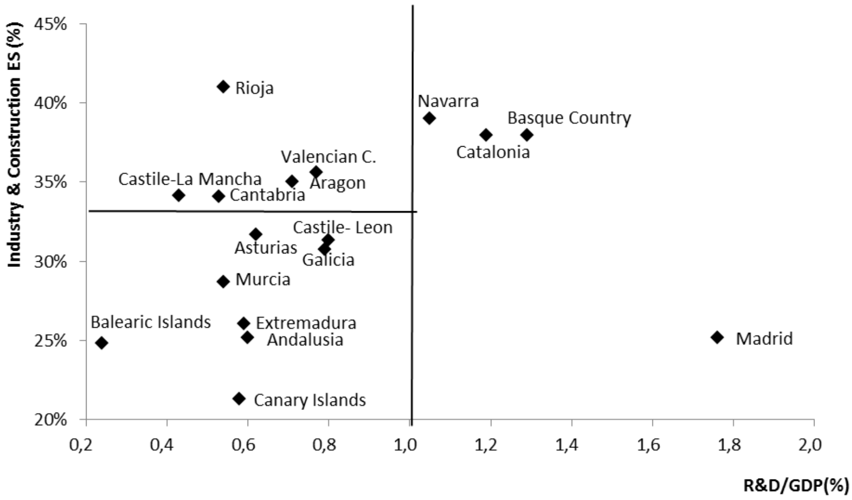
3.1 Contextual framework

The present paper focuses on Spain, a context seeing as having an unitary institutional university structure (Schubert *et al.*, 2014). The study adopts a regional-institutional-level perspective to gauge the relation between university specialization and regional HC endowment. The rationale of adopting a regional perspective is that HEIs are autonomous institutions with administrative and financial management depending on regional government since the Spanish Higher Education Reform of 1983. At the same time, the reality of Spain can be analysed as a whole by virtue of a homogeneous legal framework with respect to the conception and the functions of HEIs as well as to their objectives and expected contribution via the apocryphal channels of teaching, research and ISEE.

The Spanish higher education sector includes 73 universities (INE, 2008), 48 of which are public institutions while the remaining 25 are private. Universities are some of the most important agents in the Spanish R&D system in that they account for 27.7% of total R&D expenditure, 47.1% of employment of full-time researchers in 2012. However, most of this goes to public universities, which represent a quarter of total R&D expenditure and almost half of all researchers in Spain. The importance of these public institutions in the Spanish research system puts them at the core of this analysis[5]. Public universities are distributed unevenly across 17 regions (NUTS2), Andalusia being the region with the highest number of universities (9) followed by Catalonia and Madrid with 7 and 6 HEIs respectively[6].

[4] For more information see Sánchez-Barrioluengo (forthcoming).
[5] The National Distance Education University is excluded because it is the only Spanish distance university and is the only university that continues to be administered by national government.
[6] Valencian Community has 5; Castile-Leon, 4; Galicia, 3; Murcia and Canary Ireland, 2 and other regions 1 university.

Figure 1. Characterization of Spanish regions



Source: INE. Labor Force Survey (1999-2002) & R&D survey (2002)

Spanish regions exhibit remarkable differences due to both structural and contingent factors (Buesa *et al.*, 2006). Our characterization of the differences across regions is based on the comparison between the production structure and a relative measure of innovation showing the position of regions at the beginning of the period under analysis. Figure 1 shows the relative positioning of each region with respect to R&D expenditure over GDP in 2002 and their average industry employment share (including manufacture and construction) between 1999 and 2002. This highlights three typologies of region: leaders, followers and laggards. Among the *leaders* are regions with higher R&D/GDP ratios, namely Madrid, Basque Country, Catalonia and Navarra. The graph reveals that the last three exhibit a stronger orientation towards manufacturing as opposed to Madrid where service sectors account for the largest share of employment. The rest of regions differ in the composition of their labor market. Murcia, Extremadura, Andalusia, both Islands (Canary and Balearic), Asturias, Galicia and Castile-Leon are regions focus on the service sector -with employment shares in industry and construction lower than the national mean (31.7%) - and compose the *laggard* group. Finally, the rest of regions (Rioja, Valencian Community, Aragon, Cantabria and Castile-La Mancha) result in the group of *followers* because with similar shares of employment in industry and construction to some of the leader regions, they are not able to achieve similar R&D rates.

3.2 Data and variables

Our empirical analysis combines data from different sources. To describe the composition of employment we refer to the Spanish Labor Force Survey (LFS) containing information about occupations based on the Spanish national occupation classification (CNO), across sectors (1-digit information for both occupations and sectors). To include information about wages, we merge LFS with the Spanish Structural Salary Survey (SSS) using common occupational codes as a link. These are subsequently matched with information on occupation-specific task content from the O-NET abilities survey of the US Department of Labor. This database includes information about task content of the American occupations based on the Standard Occupation Classification System (SOC) at 2-digits. The data sets are merged by using the International Standard Classification of Occupations (ISCO-08) as reference[7]. Annex I includes the correspondence between original SOC information and Spanish CNO data used in the analysis. Third, we include information for Spanish universities from different sources: Ministry of Education (ME) data on students and researchers; National Statistics Institute (INE) statistics on higher education; Conference of Spanish Rectors (CRUE) biannual report *"La Universidad Española en cifras"* (Spanish universities in figures) for academic, productive and financial information; Spanish Patent and Trademark (OEPM) information on patents; and RedOTRI, the Spanish Network of University Knowledge Transfer Offices, for third mission indicators. Lastly, we include information related to regional supply and demand of HC (related to infrastructures, production structure and technology) collected from different sources. Data construction and measurement are detailed below. Further details are provided in Annex II.

Task variables

The US Department of Labor's O-NET abilities survey is the main source of information to compute our task variable. This is a comprehensive database of worker attributes and job characteristics built on the basis of questionnaire responses from both job incumbents and occupational analysts.[8] O-NET data are regularly updated and adapted to keep up with changes in the labor market. In particular, occupations are

[7] More information available at: www.ilo.org/public/english/bureau/stat/isco/index.htm

[8] For further information on data collection as well as critical issues of O-NET, see the comprehensive book by Tippins and Hilton (2010).

added, reclassified or eliminated in accordance with periodical revisions of the SOC structure. Also, scores of worker characteristics increase or decrease as a result of changes in perceived importance. For the purposes of the present paper we created a unique dataset of 855 four-digit SOC occupations that accounts for all revisions between 1999 and 2010[9]. O-NET information is matched with the Spanish LFS for the period 2002-2012 following other works such us Anghel *et al.* (2013).

LFS data are collected quarterly by the Spanish Statistical Office[10] and covers a sample of the population that is representative at regional and local level (autonomous communities and provinces). It includes information about the profile of the interviewee and employment and employer characteristics. We adapt the micro-data available using the following criteria. First, we consider individuals that are 16 years old or more (this is the legal working age in Spain), and who are employed at the time of the interview. Secondly, we select private sector workers as non-public/cooperative workers. Third, each interviewee is assigned to the region in which (s)he works.[11]

The LFS does not include information on wages. To deal with this drawback we use the Spanish Structural Salary Survey[12] (SSS) in 2002. This is built on a questionnaire that includes information on annual wages and number of hours worked by individuals. Using this we calculate the average hourly wage for the CNO principal group (adapted from ISCO-88). Since this is a unique code, we re-assign the classification of SSS codes to CNO 1-digit as proxy of the occupations. The correspondence between both surveys is also explained in Annex I.

Recall that the central idea of the 'task approach' is that a job encompasses multiple activities, and that occupation-specific tasks provide a measure of the skills that workers are expected to possess to perform that job (Autor, 2013). The key dimensions for our variables of interest are job-specific characteristics such as e.g. communicating with others (non-routine interactive –NRI-), interpreting meaning of information (non-routine cognitive –NRC-), janitorial services (non-routine manual –NRM-), performing

---

[9] More information available at Consolit *et al.* (2013).

[10] More information available at: www.ine.es/en/inebaseDYN/epa30308/epa_inicio_en.htm

[11] Two autonomous cities (Ceuta y Melilla) have been excluded on the basis of their significant differences with other Spanish regions and because they do not have own universities located in their regions.

[12] More information available at: www.ine.es/jaxi/menu.do;jsessionid=31DE0E88E1657341920651DD7A866D46.jaxi01?type=pcaxis&path=/t22/p133&file=inebase&L=1

administrative activities (routine cognitive –RC-), performing physical activities (routine manual –RM-). The scores contained in the survey permit the creation of task vectors that are specific to each occupation. While basic tasks are common to most jobs, a particular combination of scores for each task is a distinctive, and thus useful, characteristic.

Following the seminal paper by Autor, Levy and Murnane (2003), our task constructs are built from a detailed examination of O-NET Work Activities and Work Context, i.e. the scores in basic tasks. The main task categories are computed by summing the score of importance for a particular SOC occupation. O-NET decomposes the information for 2-digit occupations that we regroup into the Spanish CNO 1-digit as described in Annex I. Taking into account that the main objective of this work is the analysis of the influence of university orientation, we consider that HEIs should influence mostly non-routine tasks (humans retain a cognitive comparative advantage at NR activities) and the index of non-routine task intensity (NRTI) for is as follows:

$$NRTI_{ijrt} = \left[\frac{NRC + NRI + NRM}{RC + RM} \right]_{\hat{\imath}} * EmpSh_{ijrt}$$

where NRC,NRI, NRM, RC and RM are the task constructs outlined above for occupation i. $EmpSh_{ijrt}$ refers to the employment share in occupation i=1,…8 and sector j=1,…10 for the region r=1,…17 and the year t=2003,…,2010, constructed using data at the 1-digit sectors and 1-digit CNO from LFS. Unlike previous studies such us Autor, Levy and Murnane (2003), Acemoglu and Autor (2011) and Goos *et al.* (2009) that measure the employment share (ES) of occupations ranked according to initial levels of non-routine skill content. Rather we follow Consoli *et al.* (2013) in considering that employment shares capture both changes in the ES between occupations and changes in non-routine skills within occupations. In so doing we measure the intensity of non-routine tasks in each occupation-sector for the 17 Spanish regions along a period of eight years.

University orientation index (UOI)

The second key index for our analysis is elaborated to account for university orientation. The inclusion of the "task approach" from this point of view is a twofold novelty: on the one hand, the literature on skills and inequality has not used information about the suppliers of HC; on the other hand the addition of alternative HC measures as per the conceptual background above, is a contribution to the literature of economic geography. Assuming that university missions can be treated as constructs and that the activities which HEIs engage are the "materialization" of these strategies, we use 20 performance indicators[13] to construct our index for the time-window 2003-2010. Specifically, we include three indicators to measure the first mission or teaching: enrolled students (Ind_1), graduates (Ind_2) and teaching revenues (Ind_3); eight indicators to measure the second mission or research: postgraduate students (master and PhDs – Ind_4, Ind_5-), number of theses (Ind_6), research projects (number and income –Ind_7, Ind_8-) and publications (in Spanish, foreign and ISI journals –Ind_9, Ind_{10}, Ind_{11}-); and finally, nine indicators to measure the third mission or ISEE: number of patents (applications and granted -Ind_{12}, Ind_{13}-), income from projects in collaboration with firms (Ind_{14}), contract research income (Ind_{15}), revenues from R&D contracts (Ind_{16}), consultancy (number and revenues -Ind_{17}-Ind_{18}-), royalties (Ind_{19}) and spin-offs (Ind_{20}).

The panel information is used to calculate the university orientation index (UOI) for each university individually as follows:

$$UOI_{it} = \left[\frac{\overline{M2} - \overline{M3}}{|\overline{M1}|} \right]_{\hat{i}t} \text{ ; where } \begin{cases} \overline{M1}_{it} = \dfrac{Ind_1 + ... + Ind_3}{3} \\ \overline{M2}_{it} = \dfrac{Ind_4 + ... + Ind_{11}}{8} \\ \overline{M3}_{it} = \dfrac{Ind_{12} + ... + Ind_{20}}{9} \end{cases}$$

$\overline{MX}_{it}$ is the average relative effort of university i=1,..,47 in the first, second and third mission respectively in each year=2003,…,2010 weighted by the number of indicators included to measure each mission. The university index UOI measures the difference between the average value of indicators composing second mission and those grouping in the third mission, divided by the absolute value of the mean for those included in the first mission. This novel index captures in a synthetic way the relative importance of

[13] Original values of the indicators have been transformed in order to make them comparable. First, each indicator is defined as the cumulative value for activities in two consecutive years because information is available biannually. Second, to cover the full period odd years (t-1) include the same information that even years (t). Third, we normalize variables because indicators have different unit of measurement. Fourth, teaching indicators are controlled by university size by means of the division of the real value of the indicator by the number of doctoral researches in each university. Finally, we use imputation techniques to avoid missing values. A detailed explanation about the selected indicators and their validity to measure mission constructs is available at Sánchez-Barrioluengo (forthcoming).

university engagement by assigning key HEIs activities to a particular mission construct. In particular, if the value of the index is positive and high, the university is more research intensity; on the contrary, if the index is negative and low, the university presents a third mission intensity; lastly, if index is close to 0, HEIs focus mainly on teaching activities.

Finally, using information on individual universities, we construct the UOI at regional level taking into account the location of the institution. In this case UOI for region r=1,…,17 in each year t=2003,…,2010 is defined as the sum of the UOI value of the universities located in region r divided by the total number of universities that this region has:

$$UOI_{rt} = \frac{\sum_i UOI_{it}}{\#univ.r}$$

<u>Supply variables</u>

Previous studies on the connection between human capital and economic performance (see e.g.Barro, 1991) use basic indicators of educational stock, such as school enrolment rates, as proxies for the stock of human capital. Specifically the type measures are the number or percentage of primary, high school, or university graduates, different measurements of the educational attainment of the population, or even indicators of the quality of the education provided give precious little information about the use a society is making of its educational stock (Rodríguez-Pose and Vilalta-Bufí, 2005). For the purpose of this paper we use five indicators of education: percentage of people that has reached the following levels of studies: bachelor (BA), professional training (PT), higher education short and long degrees (HE short and HE long respectively)[14] and postgraduates (PG); and are performing a specific occupation i=1,…8 within the sector j=1,...10, in region r=1,…17 for the period 2003-2010. We leave out in the analysis low educated people as the reference category. This information comes from the LFS and counts the percentage of people who answer the survey in each education level for each region divided by the total number of people answering for this region.

<u>Demand variables</u>

[14] Spanish Higher Education system distinguished between short degrees (3 years) and long degrees (5 years) before the Bologna Plan that equated the Spanish and European systems.

Coherent with the conceptual framework laid out above, we control for a range of region-specific characteristics to highlight other demand variables over time. We include information relating to three basic constructs: production structure, infrastructure and technology. Annex II includes a summary table with the description of the main variables as well as the source of information.

For what concerns production structure, we include two measures: R&D expenditure and percentage of High Technology manufacture firms *(HT manufacture).* The former is calculated as the R&D/GDP ratio and is the traditional measure used to account for innovation performance (Griliches, 1979). At the same time, much of the research and development (R&D) activity in Spain occurs at universities. Such activities can also raise local HC levels if there are spillovers into the local economy that increase the demand for HC, whether such human capital is produced locally or not (Abel and Deitz, 2012). On the other hand, HT manufacture firms is measured by the percentage of firms that are defined as high tech following the taxonomy proposed by OCDE (1997) -that are derived from aggregate industry characteristics. Some studies demonstrate that the shift in demand away from unskilled and toward skilled labor in U. S is due mostly to increased use of skilled workers within the manufacturing industries in U. S. rather than to a reallocation of employment between industries (Berman *et al.*, 1994).

Second, based on the idea that an increment in the instructiveness is related to the diffusion of the improvements in communication and transport technologies (Michaels *et al.*, 2013), we analyze the role played by improvements in both technologies. In the case of transport, we include two measures related to regional infrastructures: the highest investment in infrastructures from 2000s in Spain has been the High Speed Train (AVE for its name in Spanish), with only one line between Madrid and Seville before this date and more than 3.100km nowadays. As the measurement of AVE km is related to the geographical extension of the region, we have chosen as a measure of infrastructure the number of AVE stations weighted by the number of provinces that each region includes. We count a new station in a region when a new AVE line is open. Complementary, the low cost firms have increased the use of commercial flights recently. For this reason, the second variable related to regional infrastructure that we include in our analysis is the percentage of air passengers for each 1,000 habitants in each region over the period.

Finally we include a variable to account for the technological infrastructure in each region using a proxy of the ICT measured by the percentage of firms with internet access. This is preferred to percentage of computers because the majority of internet access within firms occurs via computers. Recent studies demonstrate that contextual characteristics influence technology penetration rates (Chinn and Fairlie, 2010).

3.3 Methodology

We analyze the dataset in two different ways. First, we use simple descriptive statistics to uncover defining characteristics of local labor markets, and the orientation of universities. Secondly we employ econometric methods to examine how regional level of education, production structure, infrastructure and technology impact on the labor market, measured by task performance within occupations-sectors. We do this for the whole sample and then subdivide it according to regional innovation characteristics between those that are leaders, followers or laggards. In order to exploit the panel nature of the data, we employ two methods: fixed effects (FE) estimators and the Generalized Method of Moments (GMM) system estimator (Arellano and Bover, 1995; Blundell and Bond, 1998) for dynamic panel models (Wooldridge, 2008). The general idea of dynamic GMM estimators is to instrument the lagged dependent variable with its lags or lagged differences. This type of estimator reduces the small-sample bias of the differenced-GMM (Arellano and Bond, 1991) when the endogenous variables are persistent. This is appropriate to the data under analysis considering that demand and supply of skills change slowly over time (Consoli *et al.,* 2013).

The procedure in both methodologies, FE and GMM, consists in, first, developing a baseline model that only include the main variable of our analysis (OUI) and subsequently to include all the variables outlined above. Our specification for the dynamic panel data model is:

$$NRTI_{ijrt} = NRTI_{ijr(t-1)} + \beta_1 UOI_{rt} + \mathrm{B}X^{'}_{ijrt} + \Gamma X^{''}_{rt} + \alpha_{ijr} + \mu_t + \varepsilon_{ijrt}$$

where $NRTI_{ijrt}$ is the HC endowment in occupation i, sector j, region r and time t. UOI_{rt} is the synthetic index to measure the influence of university orientation in the model. $X^{'}_{ijrt}$ is a matrix of the supply HC; $X^{''}_{rt}$ is a matrix of the demand of HC (including production structure, infrastructure and technological variables); α_{ijr} denotes time-invariant occupation-sector-region specific effects; μ_t is the time-effect and ε_{ijrt} is an error term. The distinction between supply and demand effects is related to the selection of endogenous variables: only demand variables are included as instrumental variables (IV-style) while lagged NRTI is an endogenous one (GMM-style).

4 Main results

This section presents the analysis for the demand and supply of HC across Spanish regions as an evidence of the technological change. Results are divided in three sub-sections. First, we focus on changes in patterns of employment and the evolution of inequality in skilled-biased technological change at regional level. Second, we analyze the position of regions in the Spanish labor market according to the orientation of their universities. Finally, we show the influence of university orientation on regional human capital endowment.

4.1 Changes in employment patterns

Figure 2 shows the percentage of change between 2002 and 2012 in each occupations ordered by the average wage per hour level at the beginning of the period (2002). In the whole period (2002-2012) the first result is the strikingly non-monotone growth of employment by occupation when they are ordered by mean wage. In fact, the line linking the value of the employment share shows a twisting effect: occupations located at both tails of the wage distribution presents a positive growth in employment share while central occupations are decreasing. In this case, at the lower tail, farm and service occupations, and at the upper tail, professionals and managers, relative gains employment; while in the middle of the distribution, construction and maintenance, products and operators, office and administrative staff and technicians present relative employment declines, resulting in a U-shaped distribution. The pattern is broadly coherent even when we break down into sub periods. Arguably, this is a symptom of employment *polarization* which is common to several other countries (Goos and Manning, 2007). Moreover, the rise of service occupations at the lower end of the earnings distributions observed here matches the key findings of a recent study by Autor and Dorn (2013) for the US.

Figure 2. Changes in employment share by occupation groups (2002-2012): occupations ordered by average wage level

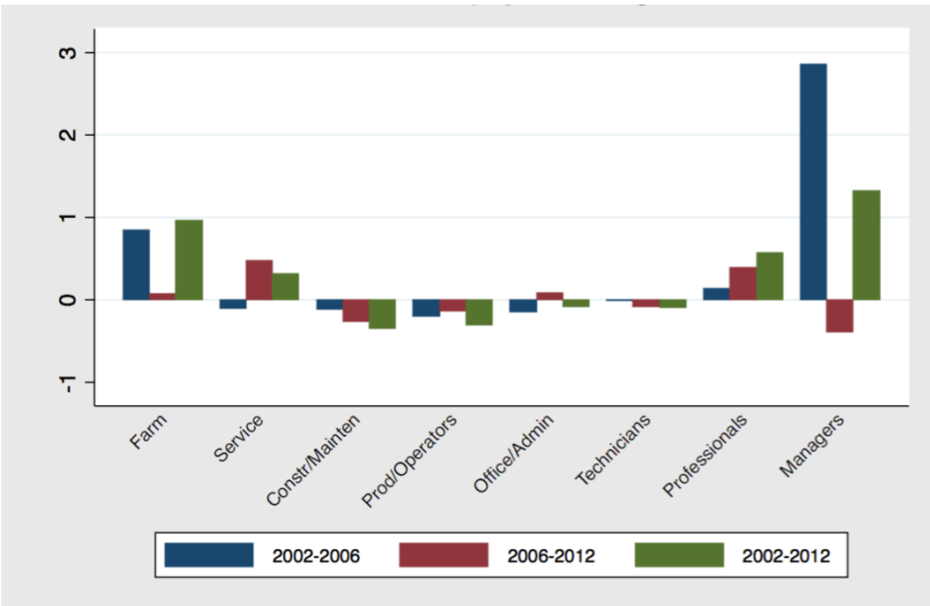
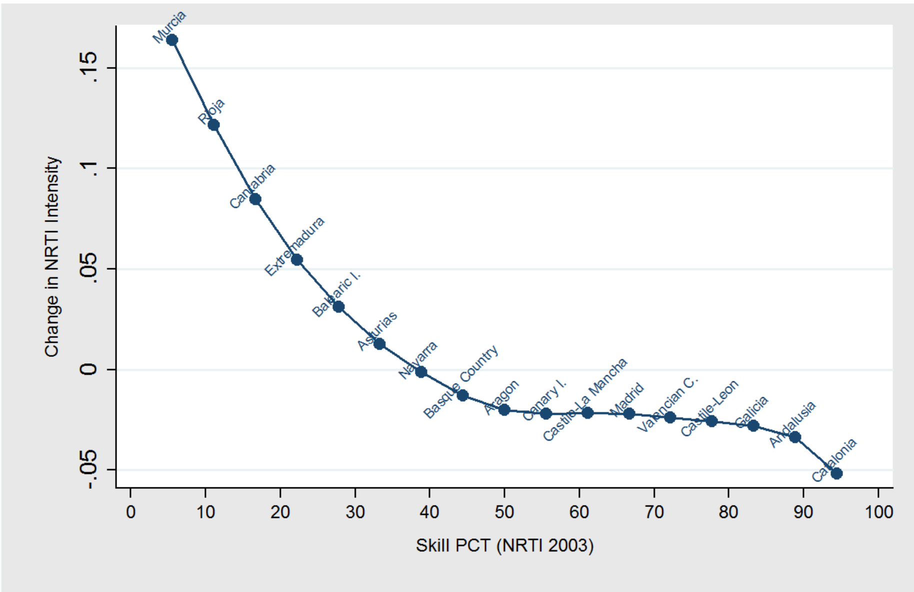


Figure 3. Regional smoothed technological change by skill percentile, 2003-2010: regions ordered by NRTI (2003)



Let us now focus on regional skill-based technological change by looking at the relative change in task intensity of Spanish regions. Figure 3 shows the regional change in NRTI ranked by initial values of the index in 2003. Here we observe that regions that were historically specialized in non-routine intensive occupations experienced differential change in HC skills. While regions located below the 40% of the non-routine distribution in 2003 try to gain advantage and achieve other advantaged regions. In fact, this graph shows that the highest positive growth change for NRTI appears in that regions that were mainly routine-based, such as Murcia, Rioja, Cantabria or Extremadura (above 0.05%). Those located in the second third does not experiment a technological change in terms of the skills of their HC, although the NRTI decreases mildly.

4.2 Changes in university orientation across regions

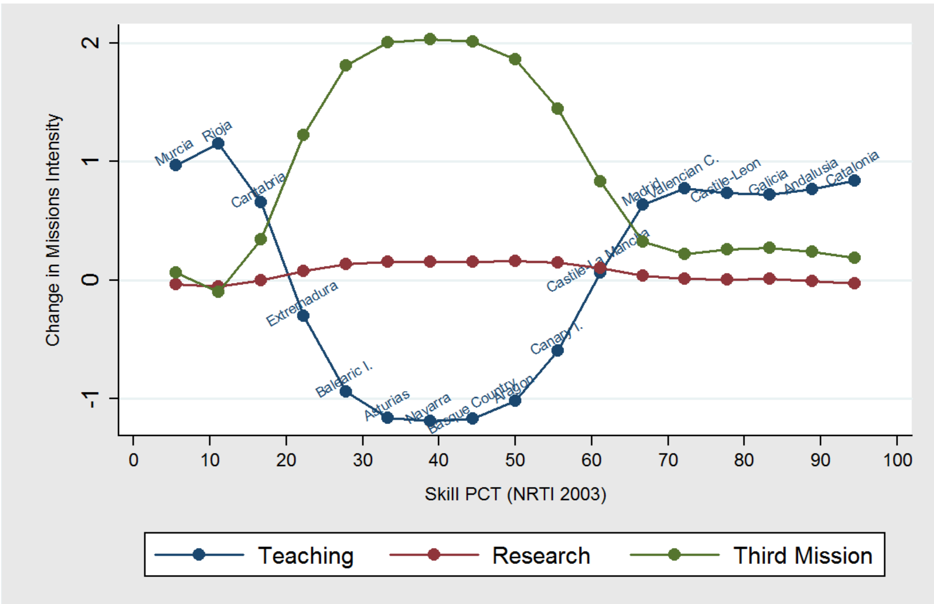
Taking into account the division of Spanish regions between leaders, followers and laggards, differences in terms of the university orientation are described in Table 1. This table shows the relative orientation of each region along the period. In the case of *leader* regions, they are clearly divided between those with a research-oriented mission (Catalonia and Basque Country), probably related to the business culture that characterize these regions; and knowledge transfer oriented, as the case of Navarra and Madrid. On the opposite side, *laggards* are mainly teaching-oriented, and universities located in these regions are contributing to HC development through teaching activities. This result is in line with other authors that demonstrate the relative low level of interaction that non-academic actors present in peripheral regions (Pinto *et al.*, 2013).

Table 1. UOI index (mean values) according to regional groups

Group	Region	UOI index	UOI value
Leaders	Navarra	Third Mission oriented	-0.2572
	Madrid	Third Mission oriented	-0.1809
	Basque Country	Research oriented	0.1921
	Catalonia	Research oriented	0.4049
Followers	Valencian Community	Third Mission oriented	-0.6785
	Rioja	Third Mission oriented	-0.4099
	Cantabria	Third Mission oriented	-0.1647
	Castile-La Mancha	Teaching oriented	0.0060
	Aragon	Teaching oriented	0.0071
Laggards	Asturias	Research oriented	0,2211
	Castile-Leon	Third Mission oriented	-0,2013
	Murcia	Teaching oriented	-0,0988
	Balearic Islands	Teaching oriented	-0,0320
	Extremadura	Teaching oriented	-0,0263
	Galicia	Teaching oriented	-0,0208
	Andalusia	Teaching oriented	0,0032
	Canary Islands	Teaching oriented	0,0238

After the analysis of the technological change in the first section, here we highlight the relative university orientation according to the regional position in the skilled labor market. First we present the relative mission intensity for each region when these regions are ordered by the non-routine intensity in 2003 (Figure 4). To build, for example, teaching intensity scores in each region, we calculate the ratio between the difference in the first mission indicators in 2010 and 2003 (numerator) and the mean difference between these years for the three missions (denominator). We repeat the same methodology for research and third mission changing the numerator in each case as appropriate. Two key messages are derived from Figure 4. First, a substitution effect between teaching and third mission tends to occur in Spanish regions, while research tends to not change over the time. This means that those regions that experiment higher positive change in third mission intensity, also show a negative growth for their first mission intensity. Second, and aligned with previous result, this dispersion affect further to those regions located in the middle of the skilled distribution in 2003. Regions in the tails of the skill distribution show higher positive growth in teaching activities, while research and third mission are close to absence of change.

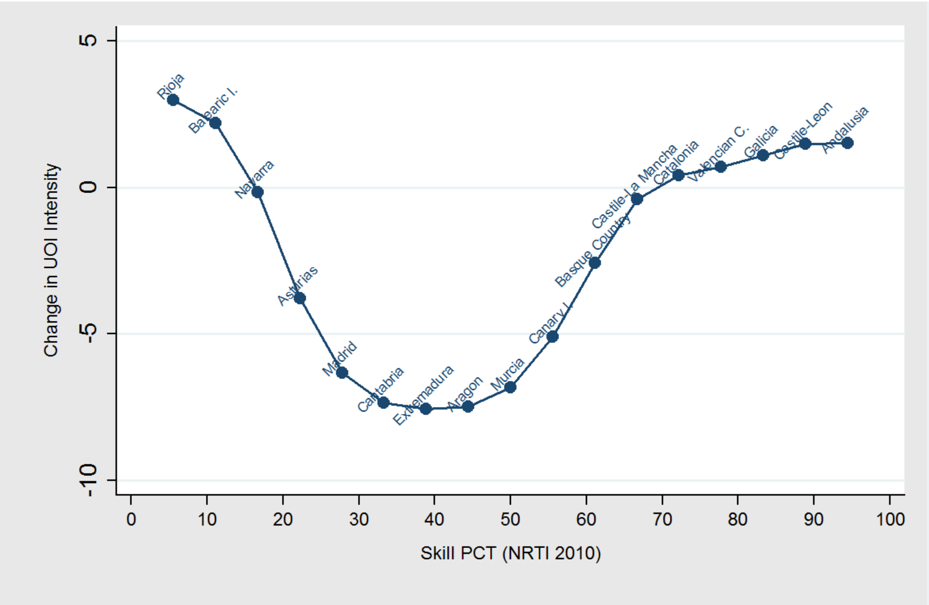
Figure 4. Relative Mission intensity by NRTI (2003)



Subsequently, in addition to the relative mission intensity, we present our synthetic indicator measuring university orientation and the position of universities in the Spanish labor market at the end of the studied period (2010). The objective here is to establish a relationship between changes in UOI and the dynamics of the change towards non-routine jobs. Taking into account the construction of our index, a positive change in UOI implies a movement towards higher research intensity regions, while negative changes suggests a shift of focus on knowledge transfer activities; otherwise, regions located around the 0 do not exhibit changes in orientation. In the latest case, if we want to observe the relative missions intensity for regions without change is necessary to analyze jointly Figure 4 and 5.

Figure 5 shows a clear U-shaped distribution whereby regions located in lower and upper tail of the skill distribution experience a positive change in the orientation of their universities (moving towards more research intensive activities), as opposed to the negative change in those located in the middle of the distribution (moving towards third mission activities). The comparison between Figure 4 and 5 suggests interesting insights. On the one hand, regions with the highest non-routine jobs located in the upper tail of the distribution in 2010 do not change the orientation of their universities (because the % of change is close to 0). These regions, Catalonia, Valencian Community, Galicia, Castile-Leon and Andalusia, were also in the upper tail in 2003 (Figure 4), showing higher intensity in teaching activities than the other two university missions. Similarly, Murcia and Cantabria were located at the lower tail of the non-routine distribution in 2003, and the effort of moving the orientation of their universities towards teaching activities has allowed them to be positioned in the middle of the distribution in 2010, improving their position in the Spanish skill labor market. On the other hand, although universities in Navarra do not change orientation (change UOI close to 0), their efforts were mostly aimed at third mission activities (Figure 4), which implies a movement towards more routine employment. This corroborates the role of teaching activities as influencing technological change towards non-routine activities.

Figure 5. Relative UOI intensity by NRTI (2010)



4.3 University orientation and local labor market

The final step is the analysis of the influence of university orientation in the configuration of the local labor market through econometric models. We regress our university orientation index (UOI) on the NRTI controlling for other demand and supply variables. Although some of the extant literature use the percentage of people at different levels of education, our index is an alternative measure of the HC. For this reason we check that both variables do not present problems of correlation and can be included in the regression model as independent variables (see Annex III). The small values of the correlation matrix imply that our variables does not present limitations related to correlated results. Table 2 and Table 3 include the results of the regression analysis in both FE and GMM models for the full Spanish regions and subdividing these regions according to their innovation performance position respectively. First, we will check the goodness of fit of the FE model and autocorrelation and overdispersion of the GMM models. On the one hand, FE models are well-defined because F-statistics are significant in all models, except for the baseline in the case of *follower* regions. In addition the R-squared moves between around 7% and 32% for the full models, being the case of *laggards* where the selected variables allow lower levels of explanation. On the other hand, right side of the tables presents the statistics for the GMM models. In this case two types of indicators serve to measure that model fits. The null hypothesis for the first-order autocorrelation, AR(1), is that autocorrelation is present in the model while the null hypothesis in the test for second-order autocorrelation, AR(2), is that there is no autocorrelation (Andersson and Kostery, 2011). In our case all full models present satisfactory AR(1) and AR(2) values for the test because the null hypothesis in the AR(1) test is rejected, and the null hypothesis in the AR(2) test is not rejected. Additionally, we validate the overidentifying restrictions through the Hansen test. Here the null-hypothesis is not rejected, meaning that the number of instruments included in the model is satisfactory. Complementary to this results, our models move between 16 and 28 instruments (baseline and full models respectively) which is less that the number of observations in all cases, guaranteeing that we are not incurred in the problem of having too many instruments (Roodman, 2006). As such, this approach enables a more causative interpretation than fixed effects models. Consequently, we focus on the results obtained using the two-step system GMM estimator for the full model.

Table 2. Panel data model of human capital endowment for the whole sample (2003-2010)

	FE Model		GMM Model	
	Baseline	Full	Baseline	Full
UOI	0.0003***	-0.0001***	0.0005***	0.0010***
	[0.000]	[0.000]	[0.000]	[0.000]
NRTI-1			-0.0953	0.1004
			[0.115]	[0.148]
Supply				
% BA		0.0000		-0.0000
		[0.000]		[0.000]
% PT		-0.0000		0.0001
		[0.000]		[0.000]
% HE short		-0.0000		0.0005**
		[0.000]		[0.000]
% HE long		0.0000*		0.0005***
		[0.000]		[0.000]
% PG		-0.0000		-0.0011*
		[0.000]		[0.001]
Production structure				
% R&D/GDP		0.0055***		-0.0006
		[0.000]		[0.001]
% HT manufacture		0.0034***		-0.0031*
		[0.000]		[0.002]
Technology				
% ICT		-0.0000		-0.0003***
		[0.000]		[0.000]
Infrastructure				
AVE stations		-0.0007***		0.0035***
		[0.000]		[0.001]
Air passengers/1000hab.		-0.0000***		0.0000***
		[0.000]		[0.000]
Observations	9410	9410	8935	8935
N. of groups	1300	1300	1243	1243
R2	0.014	0.151		
Adjusted R2	0.014	0.150		
Log-likelihood	43308.67	44011.83		
F	1142.93***	233.65***		
AR1 crit. prob.			0.000	0.000
AR2 crit. prob.			0.030	0.375
Hansen J			42.969	2.255
Hansen crit. prob.			0.000	0.972
Instruments			16	28

* p<0.10; ** p<0.05: *** p<0.01

Results in Table 2 support the conjecture that university orientation matters for the HC endowment of a region. This means that the higher the UOI is, the higher the regions' NRTI. In other words, labor markets of research-focused regions tend to accommodate cognitive jobs. The lagged non-routine task intensity for the full model present a positive but no-significant sign, which implies that previous human capital skills tend to have an effect on current composition of the labor market in a region after controlling for other supply and demand effects. A possible explanation for the lack of significance could be the short time-window under analysis. On the other hand, our synthetic indicator is a good predictor while overall educational attainment has less importance. Only high levels of education present a significant effect in the skilled distribution of HC. In this case, graduate students increase non-routine intensive jobs in regions while postgraduates have a negative effect. This results are in line with literature showing that traditional measures of educational stock have less connection to economic performance (Rodríguez-Pose and Vilalta-Bufí, 2005). Looking at the demand side of the global model, production structure variables are not extremely significant for NRTI, while technology and infrastructures influence negative and positively in our dependent variable respectively.

Latest results can be influenced by regional differences explained above in relation to the relative position of regions within the Spanish innovation system. Table 3 captures these differences and analyzes how the effect of supply and demand variables varies across *leader, follower* and *laggard* regions. Looking at the full GMM model, we observe differential engagement of university missions across regions: research-oriented universities influence HC endowment towards non-routine jobs in those regions with higher levels of invest in R&D activities (*leaders*), as well as in those regions with lower levels of R&D expenditure but where the employment share is defined by industry and construction sector (*followers*). However, the labor market of regions without previous characteristics (*laggards*) is not significant influenced by UOI index. This may depend on how the index was built. Values of UOI close to 0 means a teaching-oriented region, and a regression model test the null value of the coefficient, which could dilute the effect of teaching-oriented regions. HC trajectory is also positive for all full models, although no significant, as a symptom of the path dependency in HC characteristics and labor market composition. Similar results as the global model appear for variables measuring levels of education: graduates are positive related to HC endowment for *laggard* regions, while postgraduates are negative related for them and also for *leader* regions. None of them are significant for *followers*. Finally, while R&D expenditure and AVE stations increase non-routine jobs for *leader* and *follower* regions, HT firms decrease them for the latest. Air passengers are only related to human capital endowment for *followers*.

Table 3. Panel data of human capital endowment for regional subdivision (2003-2010)

	FE Model						GMM Model					
	Leaders		**Followers**		**Laggards**		**Leaders**		**Followers**		**Laggards**	
	Baseline	Full	Baseline	Full	Baseline	Full	Baseline	Full	Baseline	Full	Baseline	Full
UOI	0.0004***	0.0002***	0.0003	-0.0001	-0.0005***	0.0001***	0.0005***	0.0009***	0.0020*	0.0028**	-0.0018***	0.007
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]	[0.001]	[0.001]
NRTI-1							-0.2765	0.1066	-0.1593*	0.1127	0.1616	0.3263
							[0.183]	[0.168]	[0.089]	[0.201]	[0.144]	[0.210]
Supply												
% BA		0.0000**		-0.0000		0.0000		-0.0001		0.0001		0.0004
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
% PT		-0.0000		-0.0000		-0.0000		0.0000		-0.0001		0.0003*
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
% HE short		0.0000		0.0000		-0.0000		-0.0002*		0.0000		0.0008*
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
% HE long		-0.0000		0.0000		0.0000**		-0.0002*		0.0002		0.0007***
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
% PG		-0.0000		-0.0000		0.0000		-0.0017***		-0.0018		-0.0000***
		[0.000]		[0.000]		[0.000]		[0.001]		[0.001]		[0.001]
Production structure												
% R&D/GDP		0.0030***		0.0075***		0.0083***		0.0049**		0.0084**		0.0085
		[0.001]		[0.000]		[0.000]		[0.002]		[0.004]		[0.007]
% HT manufacture		0.0036***		0.0051***		0.0038***		0.0080*		-0.0214***		0.0007
		[0.001]		[0.000]		[0.000]		[0.004]		[0.007]		[0.006]
Technology												
% ICT		-0.0000***		0.0000***		-0.0000**		-0.0001		0.0000		-0.0004**
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Infrastructure												
AVE stations		0.0057***		-0.0019***		-0.0054***		0.0111***		0.0095***		0.0032
		[0.000]		[0.000]		[0.000]		[0.002]		[0.000]		[0.005]
Air passengers/1000hab.		-0.0000***		-0.0000***		-0.0000***		-0.0000		0.0000**		0.0000*
		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]		[0.000]
Observations	2229	2229	4403	2728	4453	4453	2132	2132	2576	2576	4227	4227
N. of groups	307	307	607	380	613	613	297	297	360	360	586	586
R2	0.0598	0.3277	0.0011	0.3324	0.0024	0.0682						
Adjusted R2	0.0594	0.3244	0.0007	0.3297	0.0021	0.0659						
Log-likelihood	10166.98	10540.74	12953.86	13503.60	20273.24	20425.29						
F	1717.86***	361.84***	2.153	271.17***	45.54***	56.90***						
AR1 crit. prob.							0.141	0.019	0.001	0.003	0.0002	0.011
AR2 crit. prob.							0.261	0.340	0.352	0.501	0.8180	0.237
Hansen J							45.404	15.220	26.436	4.694	33.575	4.915
Hansen crit. prob.							0.000	0.055	0.0002	0.789	0.000	0.767
Instruments							16	28	16	28	16	28

Conclusions

Under the umbrella of 'knowledge economy', HC is seen as one of a better predictors of economic vitality in a region (Abel and Deitz, 2012) and universities as key hubs for the generation and circulation of high-skilled workers (Florida *et al.*, 2008; Abel and Deitz, 2012), entertaining a wide spectrum of formal and informal relations with various other actors within their regions. For this reason, governments at different leves (supranational, national, regional and local) have been concerned with the contribution of universities to the economic development and social wellbeing (Geuna, 2001).

Different approaches of the scientific literature spotlights both concepts: on the one hand, the perspective of economic geography highlights the primacy of HC for innovation, economic and employment growth, income levels and competitiveness (Barro, 1991; Barro and Lee, 1994; Glaeser *et al.*, 1995; Glaeser, 2005; Florida *et al.*, 2008); on the other hand, studies on the economics of university articulate in great detail the historical determinants of higher education and the changing relation of the latter with the attendant societal context (Wittrock, 1993; Geuna, 1999; Youtie and Shapira, 2008). For over a decade, HEIs have undergone remarkable structural and functional changes spurred by the ethos of broadening their remit. Universities are perceived as fulfilling an ever-growing spectrum of roles: contributing to social and economic development by generating research and consultancy income, embedding knowledge in students and employees, upgrading regional business environments, and potentially improving the process of regional value capture (Benneworth and Hospers, 2007) as the result of carrying out their three missions of teaching, research and third mission.

However, as the work of Sánchez-Barrioluengo (forthcoming) remarks the prototypical "one-size-fits-all" university model overlooks the complex nature of the university *qua* institution, treating them as homogenous institutions with equal capacity to perform and contribute to social engagement, as well as, we argue, the dynamics that influence demand for skills at regional level. In this case, regional factor bias may trigger selection effects on mission engagement, prolonged commitment towards a particular university mission influence the developmental path of a region and reflect the pattern of the regional HEIs due to cyclical or technological forces (Beaudry *et al.*, 2010; Autor and Dorn, 2013).

Our claim is, then, the lack of operationalization of key concepts such as HC and University Mission which are treated in these literatures, at best, only in abstract terms. In consequence, the present paper seeks to analyze the relationship between of HEIs´ mission orientation and HC endowment of their regions. We argue that the shortcomings of previous approaches are twofold: HC indicators are mostly created on direct "human capital creation" effects and no clear arguments are offered with regards to persistent differences in the ability to generate and use knowledge across regions.

On the one hand, traditional literature on HC has been centered on aggregate supply indicators considered as a function of basic inputs such as the most conventional measure along this logic is the local ratio of graduates. However, this is an incomplete indicator because neglects the demand side, i.e. the reality of local labor markets dynamics, as well as the indirect effect of the institutional processes due to university engagement via other missions. On another front, literature on skills is focused on the dynamics of labor markets and of its relation with technological change, taking into account how the environment evolves, i.e. due to the diffusion of ICT based applications. The majority of the analyses on this front are aggregate by country or at most at sector level and thus do not account for the selection forces at play in local contexts. Our contribution to these gaps is the development of an alternative indicator based on the skill content of occupations within the sectors across regions, that is, we propose that job-occupation characteristics are a better mechanism through which education is converted into skill and labor productivity. Based on the task based model approach (Autor, 2013), we calculate an index of non-routine task intensity (NRTI) as a measurement of skills needs to develop a job. This novel indicator is used to analyze the HC endowment of Spanish regions addressing a proposal focused on the structure and the dynamics of HC. In this sense, our results suggest changes in patterns of employment and the evolution of inequality in skilled-biased technological change at regional level. In general terms, an *employment polarization* effect (Goos and Manning, 2007; Anghel *et al.*, 2013; Autor and Dorn, 2013) appears in Spanish regions. This means that occupations with the lowest and highest wages (farm and services in the first case, professionals and managers in the second one) have increased their employment shares between 2002 and 2012, while middle-wages occupations experiment negative growths. At the same time looking at our specific indicator shifts between task intensity also appears. Specifically, regions that were historically specialized in non-routine intensive occupations experienced differential change in HC skills while the highest positive growth change for NRTI appears in that regions mainly routine-based.

On the basis of the questionable hypothesis that universities generate spillovers regardless of their internal capabilities and of specific regional/local societal needs, we have also computed an index of regional university orientation (UOI) that allow the measurement of individual university performance in each of the three missions. This novel index captures in a synthetic way the relative importance of university engagement by assigning key HEIs activities to a particular mission construct and allows to found differences across regions. Two important conclusions derived from this analysis. First, a substitution effect between teaching and third mission tends to occur in Spanish regions, so that those regions that experiment higher positive change in third mission intensity, also show a negative growth for their first mission intensity. At the same time, regions in the upper tail of the skill distribution show higher positive growth in teaching activities over the years, corroborating the role of teaching activities as influencing technological change towards non-routine activities. As a corollary, these results elucidate important aspects of local labor markets, especially relevant in the case of Spain due to marked differences across regions.

Related to the above, the second objective of this work has been the analysis of the determinants of HC, addressing both demand and supply dimensions mediated by institutional processes like education and labor markets. Econometric results support the conjecture that university orientation matters for the HC endowment of a region, so that labor markets of research-focused regions tend to accommodate cognitive jobs, specifically in leader and follower regions. At the same time, a path dependency between previous and current HC regional skills exists as a symptom of the importance of the regional trajectories. Measure of HC supply and demand affect differently to the skill composition of the labor market. While supply variables do not influence the routinization of jobs, factors included in the demand affects in both directions. The no significance of educational attainment of regional skill endowment is in line with literature showing that traditional measures of educational stock have less connection to economic performance (Rodíguez-Pose and Vilalta-Bufí, 2005). Differences between leaders, followers and laggards appear also in relation to how the university orientation and supply and demand variables affect to the composition of their labor markets.

In sum, the objective of this article is to shed some light on this issue by analyzing the impact of HEIs´ mission orientations on the HC endowment of their regions. On the whole this initial analysis corroborates the conjecture that university orientation plays a strong role in the process of regional economic development. From this we derive preliminary policy implications. First, our results point to the weakness of the 'one-size-fits-all' model that is usually employed in the debate on university missions. Acknowledging, rather than ignoring, these differences is a first step towards the full exploitation of university potential on the basis of the revealed pattern of specialization. Second, our analysis of the skill content of the workforce affords the opportunity of a concrete assessment of the types of know-how that are relevant to regional economic development. Skill intensity as a unit of analysis is not knowledge in abstract terms but, rather, an empirical measure of supply and demand forces filtered by the reality of the regional labor market. Last but not least, the present study offers a more nuanced view of the connection between demand and supply of knowledge as mediated by institutional processes such as education, employment and economic performance.

References

Abel, J.R. and Deitz, R. (2012). "Do colleges and universities increase their region's human capital?" *Journal of Economic Geography*, 12 667-691.

Acemoglu, D. and Autor, D. (2011). *Skills, tasks and technologies: Implications for employment and earnings*. In: (Ashenfelter, O. and Card, D.) Handbook of Labor Economics.

Andersson, M. and Kostery, S. (2011). "Sources of persistence in regional start-up rates—evidence from Sweden." *Journal of Economic Geography*, 11 179-201.

Anghel, B.;De la Rica, S. and Lacuesta, A. (2013). *Employment Polarization in Spain along the Cycle 1997-2012*.

Anselin, L.;Varga, A. and Acs, Z. (1997). "Local Geographic Spillovers between University Research and High Technology Innovations." *Journal of Urban Economics*, 42 (3): 422-448.

Arbo, P. and Benneworth, P. (2007). "Understanding the regional contribution of higher education institutions: A literature review." *OECD Education Working Paper*, No. 9

Arellano, M. and Bond, S. (1991). "Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations." *Review of Economic Studies*, 58 277-297.

Arellano, M. and Bover, O. (1995). "Another look at the instrumental variable estimation of error-components models." *Journal of Econometrics*, 68 (1): 29-51.

Audretsch, D.;Lehmann, E. and Warning, S. (2005). "University spillovers and new firm location " *Research Policy*, 34 1113-1122.

Autor, D. (2013). "The Task-Approach to Labor Markets: an Overview." *Journal of Labor Market Research*, 46 (3): 185-199.

Autor, D.H. and Dorn, D. (2013). "The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market." *American Economic Review,* 103 (5): 1553-1597.

Autor, D.H.;Levy, F. and Murnane, R.J. (2003). "The skill content of recent technological change: An empirical exploration." *Quarterly Journal of Economics,* 118 (4): 1279-1333.

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

Barro, R. and Lee, J.W. (1994). "Sources of economic growth." *Carnegie-Rochester Conference Series on Public Policy and Administration*, 40 1-46.

Beaudry, P.;Doms, M. and Lewis, E. (2010). "Should the Personal Computer Be Considered a Technological Revolution? Evidence from U.S. Metropolitan Areas." *Journal of Political Economy*, 118 (5): 988-1036.

Becker, G.S. (1964). *Human Capital*. New York: Columbia University Press.

Benneworth, P. and Hospers, G. (2007). "The new economic geography of old industrial regions: universities as global- local pipelines." *Environment and Planning C: Government & Policy,* 25 (5): 779-802.

Benneworth, P.S. (2005). "Old industrial regions (III): bringing Cambridge to Consett? Economic development policies for university spin-offs in old industrial regions." *Regions,* 259 17-22.

Berman, E.;Bound, J. and Griliches, Z. (1994). "Changes in the Demand for Skilled Labor within U. S. Manufacturing: Evidence from the Annual Survey of Manufactures." *The Quarterly Journal of Economics,* 109 (2): 367-397.

Berry, C.R. and Glaeser, E.L. (2005). "The divergence of human capital levels across cities." *Papers in Regional Science and Urban Economics*, 84 407-444.

Blundell, R. and Bond, S. (1998). "Initial conditions and moment restrictions in dynamic panel data models." *Journal of Econometrics*, 87 (1): 115-143.

Buesa, M.;Heijs, J.;Martínez-Pellitero, M. and Baumert, T. (2006). "Regional systems of innovation and the knowledge production function: the Spanish case." *Technovation,* 26 463-472.

Consoli, D., Vona, F., Saarivirta, T. (2013). "An analysis of the Graduate Labour Market in Finland: Spatial Agglomeration and Skill-Job Match". *Regional Studies* 47(10): 1634-1652.

Consoli, D.;Vona, F. and Rentocchini, F. (2013). *That was then, this is now: Skills and Routinization in the 2000s*. INGENIO Working Papers 2013/06

Chinn, M.D. and Fairlie, R.W. (2010). "ICT Use in the Developing World: An Analysis of Differences in Computer and Internet Penetration." *Review of International Economics,* 18 (1): 153-167.

Drucker, J. and Goldstein, H. (2007). "Assessing the Regional Economic Development Impacts of Universities: A Review of Current Approaches." *International Regional Science Review,* 30 (1): 20-46.

European Commission (2006). *Delivering on the modernisation agenda for universities: Education, Research and Innovation*. Place. Published. European Commission. COM(2006) 208 final.

Florida, R.;Mellander, C. and Stolarick, K. (2008). "Inside the black box of regional development—human capital, the creative class, and tolerance." *Journal of Economic Geography*, 8 615-649.

Geuna, A. (1999). *The Economics of Knowledge Production. Funding and the structure of university research*. Cheltenham (UK). Edward Elgar.

Geuna, A. (2001). "The Changing Rationale for European University Research Funding: Are there negative unintended consequences?" *Journal of Economic Issues,* XXXV (3): 607-632.

Glaeser, E.L. (2000). *The new economics of urban and regional growth*. In: (Gordon, C.;Meric, G. and Feldman, M.) The Oxford handbook of economic geography. Oxford: Oxford University Press.

Glaeser, E.L. (2005). "Reinventing Boston: 1640-2003." *Journal of Economic Geography,* 5 119-153.

Glaeser, E.L.;Scheinkman, J.A. and Shleifer, A. (1995). "Economic growth in a cross-section of cities." *Journal of Monetary Economics,* 36 117-143.

Goddard, J.;Robertson, D. and Vallance, P. (2012). "Universities, Technology and Innovation Centres and regional development: the case of the North-East of England." *Cambridge Journal of Economics,* 36 (3): 609-627.

Goddard, J.B. and Chatterton, P. (1999). "Regional Development Agencies and the knowledge economy: harnessing the potential of universities." *Environment and Planning C : Government and Policy,* 17 (6): 685-699.

Goos, M. and Manning, A. (2007). "Lousy and Lovely Jobs: The Rising Polarization of Work in Britain." *The Review of Economics and Statistics,* 89 (1): 118-133.

Goos, M.;Manning, A. and Salomons, A. (2009). "The Polarization of the European Labor Market." *American Economic Review Papers and Proceedings,* 99 (2): 58-63.

Griliches, S. (1979). "Issues in assessing the contribution of R&D to productivity growth." *Bell Journal of Economics,* 10 92-116.

Hewitt-Dundas, N. (2012). "Research intensity and knowledge transfer activity in UK universities." *Research Policy,* 41 (2): 262-275.

INE (2008). *Estadística de la enseñanza universitaria en España*. Place. Published. INE.

Klofsten, M. and Jones-Evans, D. (2000). "Comparing Academic Entrepreneurship in Europe – The Case of Sweden and Ireland." *Small Business Economics,* 14 299–309.

Levy, F. and Murnane, R.J. (2004). *The new division of labor: How computers are creating the next job market*. Princeton University Press.

Louis, K.S.;Blumenthal, D.;Gluck, M.E. and Stoto, M.A. (1989). "Entrepreneurs in academe: An exploration of behaviors among life scientists." *Administrative Science Quarterly,* 34 (1): 110-131.

Martin, B.R. (2003). *The changing social contract for science and the evolution of the university.* In: (Geuna, A.;Salter, A.J. and Steinmueller, W.E.) Science and Innovation: Rethinking the rationales for funding and governance. Cheltenhan, UK. Edward Elgar Publishing Limited.

Michaels, G.;Rauch, F. and Redding, S.J. (2013). *Task Specialization in U.S. Cities from 1880-2000*.

Moretti, E. (2004). "Estimating the social return to higher education: evidence from longitudinal and repeated cross-sectional data." *Journal of Econometrics*, 121 175-212.

Nelson, R.R. and Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Cambridge, MA. Harvard University Press.

OECD (2004). *Education at a Glance*. OECD Publishing. Paris

OECD (2008). *Tertiary Education for the Knowledge Society*. Vol 1. Special features: Governance, Funding, Quality. OECD.

Olsen, J.P. (2007). *The institutional dynamics of the European university*. In: (Maassen, P. and J.P. Olsen) University dynamics and European integration. Dordrecht: Springer.

Philpott, K.;Dooley, L.;O'Reilly, C. and Lupton, G. (2011). "The entrepreneurial university :Examining the underlying academic tensions." *Technovation,* 31 161-170.

Pinheiro, R.;Benneworth, P. and Jones, G.A. (2012). *Universities and Regional Development: A critical assessment of tensions and contradictions*. Routledge: Milton Park and New York.

Pinto, H.;Fernandez-Esquinas, M. and Uyarra, E. (2013). "Universities and Knowledge-Intensive Business Services (KIBS) as Sources of Knowledge for Innovative Firms in Peripheral Regions." *Regional Studies,* In press

Rodríguez-Pose, A. and Vilalta-Bufí, M. (2005). "Education, migration, and job satisfaction: the regional returns of human capital in the EU." *Journal of Economic Geography,* 5 545-566.

Romer, P.M. (1990). "Endogenous technological change." *Journaol of Political Economy,* 98 71-102.

Roodman, D. (2006). "A Note on the Theme of Too Many Instruments." *Oxford Bulletin of Economics and Statistics,* 71 (1): 135-158.

Rosenberg, N. (1976). *Perspectives on technology*. Cambridge University Press.

Sabel, C.F. (1982). *Work and Politics: the division of labor in industry*. Cambridge University Press.

Sánchez-Barrioluengo, M. (forthcoming). "Articulating the ‘three-missions’ in Spanish universities." *Research Policy,* Forthcoming

Schubert, T.;Bonaccorsi, A.;Brandt, T.;De Filippo, D.;Lepori, B.;Niederl, A.;Schmoch, U. and Slipersæter, S. (2014). *Is there a European university model? New evidence on national path dependence and structural convergence. A changing landscape*. In: (Bonaccorsi, A.) Knowledge, Diversity and Performance in European Higher Education. Edward Elgar Publishing.

Spitz-Oener, A. (2006). "Technical Change, Job Tasks, and Rising Educational Demands: Looking outside the Wage Structure." *Journal of Labor Economics,* 24 (2): 235-270.

Teichler, U. (1988). *Changing patterns of the higher education system. The experience of three decades*. London: Jessica Kingsley.

Teichler, U. (2004). *Changing structures of the higher education systems: The increasing complexity of underlying forces*. UNESCO Forum Occasional Paper Series Paper No. 6 Diversification of Higher Education and the Changing Role of Knowledge and Research

Tippins, N. and Hilton, M. (2010). *A Database for a Changing Economy: Review of the Occupational Information Network. Panel to Review the Occupational Information Network (O-NET).*

Uyarra, E. (2010). "Conceptualizing the Regional Roles of Universities, Implications and Contradictions." *European Planning Studies,* 18 (8): 1227-1246.

Wallsten, S. (2001). "An empirical test of geographic knowledge spillovers using geographic information systems and firm-level data." *Regional Science and Urban Economics,* 31 571-599.

Wittrock, B. (1993). *The modern university: the three transformations.* . In: (Wittrock, B. and Rothblatt, S.) The European and American University since 1800. Historical and sociological essays. Cambridge University Press.

Wooldridge, J.M. (2008). *Econometric Analysis of Cross Section and Panel Data*. Cambridge, MA: MIT press.

Youtie, J. and Shapira, P. (2008). "Building an innovation hub: A case study of the transformation of university roles in regional technological and economic development." *Research Policy*, 37 (8): 1188-1204.

Annex I. Correspondence table between SOC and Spanish CNO codes.

SOC	Spanish CON (LFS)	CNO Principal Group (SSS)
11. Management	1. Managers	A0. Dirección de las administraciones públicas y de empresas de 10 o más asalariados
13. Business and Finance 15. Computer Specialist and Mathematicians 17. Architects and Engineers 19. Scientists 23. Legal profession 25. Education and Training 29. Health Practitioners	2. Professionals	D0. Profesiones asociadas a titulaciones de 2º y 3er ciclo universitario y afines E0. Profesiones asociadas a una titulación de 1er ciclo universitario y afines
21. Community and Social Services 27. Arts and Design 31. Health Support Workers	3. Technicians and associate professionals	F0. Técnicos y profesionales de apoyo
43. Office Administrators	4. Clerical support workers	G0. Empleados de tipo administrativo
33. Protective Services 35. Food and Serving 37. Building and Maintenance 39. Personal Care Services 41. Sales	5. Service and sales workers	H0. Trabajadores de los servicios de restauración y de servicios personales J0. Trabajadores de los servicios de protección y seguridad K0. Dependientes de comercio y asimilados
45. Farm, Fish, Forestry 47. Extraction 49. Install, maintenance and repairing	6. Skilled agricultural, forestry and fishery workers 7. Craft and related trades workers	L0. Trabajadores cualificados en la agricultura y en la pesca M0. Trabajadores cualificados de la construcción, excepto los operadores de maquinaria N0. Trabajadores cualificados de las industrias extractivas, de la metalurgia, la construcción de maquinaria y asimilados P0. Trabajadores cualificados de industrias de artes gráficas, textil y de la confección, de la elaboración de alimentos, ebanistas, artesanos y otros asimilados
51. Production 53. Transport	8. Plant and machine operators, and assemblers	Q0. Operadores de instalaciones industriales, de maquinaria fija; montadores y ensambladores R0. Conductores y operadores de maquinaria móvil

Annex II. Summary of the main variables

Variable	Description	Source	Mean	SD	Min.	p25	p50	p75	Max.	N
NRTI	Ratio between non-routine (cognitive, interactive and manual) and routine (cognitive and manual) tasks	O-NET	0.08	0.01	0.05	0.07	0.08	0.10	0.12	9410
UOI	University Orientation index. If UOI>0 the region is research oriented; if UOI<0 region is third mission oriented; if UOI~0 region is teaching oriented.	INE, ME, RedOtri, OEPM	-0.07	0.91	-3.61	-0.19	-0.04	0.05	5.78	9410
% BA	% of people in each occupation-sector with bachelor studies in region r at year t	LFS (INE)	13.59	16.09	0	0	10	20	100	9410
% PT	% of people in each occupation-sector with professional training studies in region r at year t	LFS (INE)	21.04	20.94	0	0	18.04	32.81	100	9410
% HEshort	% of people in each occupation-sector with short higher education studies in region r at year t	LFS (INE)	12.22	18.18	0	0	4.55	17.78	100	9410
% HElong	% of people in each occupation-sector with long higher education studies in region r at year t	LFS (INE)	14.26	22.99	0	0	2.04	18.75	100	9410
% Pg	% of people in each occupation-sector with postgraduate studies in region r at year t	LFS (INE)	0.70	3.55	0	0	0	0	100	9410
R&D/GDP	R&D expenditure as a percentage of GDP by region (r) and year (t)	Eurostat	1.03	0.47	0.23	0.68	0.92	1.23	2.19	9410
HT Manuf.	% of High Technology manufacture firms over the total number of firms by region (r) and year (t)	INE	0.68	0.31	0.14	0.42	0.60	0.92	1.38	9410
Internet	% of firms with internet access over total number of firms by region (r) and year (t)	INE	79.48	28.29	19.01	87.58	94.9	97	99.6	9410
AVE stations	Number of High Speed Train (AVE) stations in region r over the number of provinces in that region in year t	Adif	0.26	0.43	0	0	0	0.5	1.33	9410
Pass / 1,000 hab.	% of air Passengers per each 1,000 inhabitants by region (r) and year (t)	Eurostat, AENA[1]	6.57	11.65	0.00	0.08	2.19	7.76	52.46	9410
Wage/hour	Average wage per hour in each occupations by region (r) and year (t)	SSS (INE)	14.00	7.30	7.54	9.25	9.82	18.76	29.92	9410

[1] Eurostat does not include information for Extremadura, Rioja and Castile-La Mancha. We have included the information for these regions from the AENA webpage in order to avoid missing values in our regression analysis.

Annex III. Correlation matrix

	UOI	% BA	% FP	% HE short	% HE long	% PG	R&D/GDP	Internet	HT Manuf.	AVE stations
UOI	1									
% BA	0.008	1								
% FP	-0.015	-0.055***	1							
% HE short	-0.001	-0.157***	-0.233***	1						
% HE long	0.004	-0.195***	-0.319***	0.211***	1					
% PG	-0.012	-0.066***	-0.106***	0.102***	0.166***	1				
R&D/GDP	-0.052***	-0.007	0.080***	-0.016*	0.085***	0.057***	1			
Internet	-0.175***	0.006	0.059***	-0.036***	-0.015*	0.081***	0.256***	1		
HT Manuf.	0.144***	-0.056***	0.073***	0.032***	0.058***	-0.038***	0.282***	-0.193***	1	
AVE stations	0.077***	0.044***	-0.045***	-0.023**	0.032**	0.014	0.189***	0.098***	0.147***	1
Pass / 1,000 hab.	-0.022*	0.096***	-0.086***	-0.075***	0.019**	0.034***	0.210***	0.100***	-0.328***	0.327***