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THE CONTRIBUTION OF HIGHER EDUCATION TO THE DEVELOPMENT OF INNOVATION-RELATED COMPETENCES: A GRADUATES' VIEW

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Abstract

This paper examines the production function relationship between the educational resources applied during study and the development of competences related to innovation by university graduates in Spain. The data set comes from the European graduate survey REFLEX and includes about 5500 individuals who graduated from Spanish universities during the academic course 1999/2000. The inputs, combining with students' effort, are represented by the methods of teaching and learning used in higher education. The outputs are the development of four professional competences required to innovate productively: *Alertness to new opportunities, Ability to come up with new ideas or solutions, Willingness to question the own and others' ideas, and Ability to mobilize the capacities of others.* The research hypothesis is the presence of statistically significant relationships between the development of these innovational competences by graduates and the methods of teaching and learning used at university during their studies. The relationships are modeled through a set of stochastic frontier equations with the development of each competence as the dependent variable. The input variables are the prevalence of diverse methods of teaching and the amount of time graduates devoted to study. The equations also include controls for programme length and field of study, and individual characteristics: secondary marks, father and mother's education, age and gender. The analysis is replicated using variance components models to take advantage of the clustered nature of data regarding the type of programme completed by graduates. Estimates show evidence of significant relationships between the development by graduates of competences to innovate and the methods of teaching and learning they were exposed to during their university years. Proactive methods in general, and problem-based learning in particular, appear as the most effective way to develop the competences required to innovate.

1. INTRODUCTION

Productive innovation, broadly understood as the mobilization of newly-available knowledge into the production of goods and services, has become an essential mechanism to explain success in business and, ultimately, the growth of economies. Innovation appears as the major force behind productivity gains, and therefore behind increases in living standards, in developed countries during the last three decades. The improvement of productive efficiency, quantified in aggregate terms as TFP gains, emerges mainly as a result from continuously applying new technologies and more efficient modes to organize production. Consequently, it is worth to extend and to deepen the economic analysis oriented to obtain a better understanding of innovation processes, that is, of the procedures for the generation of new knowledge and of the mechanisms through which they spread and, finally, are applied to productive, market-oriented activities.

The education of the workforce, and particularly higher education, is at the root of the original ideas generated and applied in the economies from which the technological and organizational developments arise. The diffusion of innovation also appears related to the availability of a sufficient number of people suitably instructed and in possession of updated professional competences to apply newly-available knowledge (Knabb and Stoddard, 2005). The strategic nature of education regarding innovation processes, nevertheless, have been largely ignored by the economic theories on endogenous growth. The most remarkable exception is the model proposed and partially developed in a recent paper by Lucas (2009), where productivity evolves depending on the ability and effort individuals devote to seek for and to process new ideas, which in turn depends on their own educational investments, and on the average quality and diversity of ideas in the economy, which depends on aggregate educational investment.

The creation and transmission of knowledge is the main function of higher education systems. Individuals, and society at large, devote a substantial volume of resources to universities and other higher education institutions because they are thought to exert a decisive influence on the aggregate capacity to innovate and therefore in aggregate productivity. Universities and other higher education institutions influence productivity through innovation in two main ways. First, a substantial proportion of the effort in research and development, both basic and applied, is made within the higher education system. Second, higher education institutions instruct future workers for industry and services, including those that will professionally work on R&D activities.

The professional competences acquired by the flow of new graduates emerging from higher education institutions into the labour market each year can be conceived as an expression of the multidimensional output obtained from the resources devoted to the higher education system. New graduates bring into the market their human capital in terms of the competences developed during their studies, thus increasing the volume of resources that is used to generate economic output. Among other competences, new graduates bring in the specific capacity to generate productive innovation at the workplace by creating new knowledge, or adapting knowledge recently achieved by others, and using it to perform their tasks and responsibilities in ways that increase their productivity.

Our basic assumption is that the potential for innovation of higher education graduates is a key determinant both of their professional success and of total efficiency of the production system. Therefore, higher education, as far as it constitutes an individual and collective investment, can and should contribute to develop in students the specific competences related to their potential for productive innovation at the workplace. Higher education must contribute to equip graduates with the capacities required to gain productivity by generating or adapting new knowledge and making the decision to use it along with other resources, available but previously not used, in the daily development of their tasks and professional responsibilities.

Within this context, our research question is to identify the mechanisms that channel the contribution of higher education to the development by graduates of the competences specifically required to innovate productively while performing their job tasks and responsibilities. To do so, we examine particularly the relationships between the teaching and learning modes used in higher education and the level of development reported by graduates with respect to certain professional competences that promote their capacity to generate and continuously apply new knowledge while developing their professional careers. The results of analysis, carried out by means of the estimation of diverse econometric models, illustrate how the acquisition by graduates of the competences related to innovation depends crucially on which were the modes of teaching/learning they were more exposed to during his trajectory as students, keeping constant other relevant elements involved in the educative process.

The article is organized as follows. After the introduction, section two outlines a conceptual framework to model the acquisition of competences to innovate as an output of the process of higher education. Section three describes the data set, the selection of variables and the econometric procedures applied. Section four shows and discusses the main results. Finally, section five compiles some concluding remarks to the study.

2. THE DEVELOPMENT OF COMPETENCES TO INNOVATE AS AN OUTPUT OF HIGHER EDUCATION

Economic theory postulates that people reorganize constantly the allocation of the resources under their control as a response to the changes in the surrounding economic conditions. Under the so-called *disequilibrium theory*, formulated by Schultz (1975), the efficiency of such responses depends crucially on the *allocative ability* of individuals, which, in turn, is influenced by the education received and the experience accumulated by each one. The basic idea is that better educated individuals are more productive in their economic activities as a consequence of their higher capacity to perceive and to evaluate the changing economic conditions around them, so they are able to obtain advantages by recognizing earlier the situations where disequilibria, either in the markets of input factors or in the markets of final goods, take place.

Earlier recognition of disequilibria allows educated people to be more efficient when reallocating their resources in the path to regain equilibrium.

According to this argument, the capacity for productive innovation is the main component of the *allocative ability* needed to evaluate accurately the economic conditions, generate advantages by using new knowledge in production and, consequently, to gain efficiency whenever they reallocate their resources. Productive innovation appears in this light as a process involving a sequence of activities that are undertaken continuously through the life cycle of individuals and may reach professional, economic and personal environments. To innovate productively, it is necessary, to accomplish a sequence of four different activities. First, to perceive the situation and realize the chance, or recognize the need, for improvement (detection); second, it is necessary to create, develop, or find out and adapt, a new idea that can tentatively solve the problem (acquisition); third, it is necessary to evaluate the new idea as a better solution compared to the old ways of doing things (evaluation); and finally, fourth, it is necessary to apply resources according to the new solution and, therefore, generate an increase in productivity (reallocation). In order to be able to perform these activities, individuals must possess the required capabilities. We believe that higher education contributes, up to an extent, to build up the competences required to detect chances, find solutions, evaluate them, and allocate their resources accordingly; further, we believe that the modes of teaching and learning used during studies are crucial to develop in graduates the competences required to innovate (CTIs).

Graduates' development of those CTIs by means of higher education can be understood as the result from combining the educational resources deployed at higher education institutions with the personal resources of the students, including their effort and dedication to study, and the skills acquired before higher education, as well as their natural talents (Hartog, 2001).

The amount of educational resources that higher education institutions provide to students may be evaluated through monetary measures such as the average expenditure per year per pupil. In this paper, however, we adopt a more qualitative approach by addressing the emphasis made on diverse teaching and learning modes during higher education after controlling for the type and length of the programme completed as main predictors for the volume of material resources applied to each student. The human capital resources students devote to their education are assumed to have two components following the literature on education production (Todd y Wolpin, 2003). The first one, historical, consists of the resources applied to the education of students in all stages prior to higher education; the second component, contemporary, consists of the behaviour deployed by students during their higher education years, and can be evaluated in terms of the time, effort and dedication they devoted to their higher education studies.

Finally, the choice of a specific functional form to relate input and output in the context of educational production is a relevant one because it establishes restrictions on the type of analyses that can be performed and, consequently, on the scope of the conclusions that can be reached and on the policy implications that can be derived from them (Worthington, 2001). In this paper we propose, first, the use of stochastic frontier linear models (Aigner, Lovell y Smith, 1977). Stochastic frontier equations with a composite formulation of the error term allow us to estimate the marginal effects of diverse input factors taken into account, and testing for, the possible influence of unobserved heterogeneity among individuals. Second, we replicate the analysis using variance components models (Moulton, 1987) to take advantage of the nested nature of data to clarify the effects of the type of programme completed.

3. DATA, SELECTION OF VARIABLES, AND ECONOMETRIC PROCEDURES

The data come from REFLEX (*The flexible professional in the knowledge society*), a graduate survey including some 40,000 individuals of fourteen countries who graduated from higher education institutions in 1999/2000 and who answered the survey questionnaire in 2005 (www.reflexproject.org). To analyze the production function relationship between the prevalence of diverse teaching and learning modes and the development of CTIs by means of higher education we use the information corresponding to some 5400 individuals who graduated from Spanish universities. REFLEX includes questions about graduates´ higher education, transition to education to work, earlier career stages, and current professional situation. It also includes a chapter about competences where respondents were asked two questions regarding a list of 19 capacities:

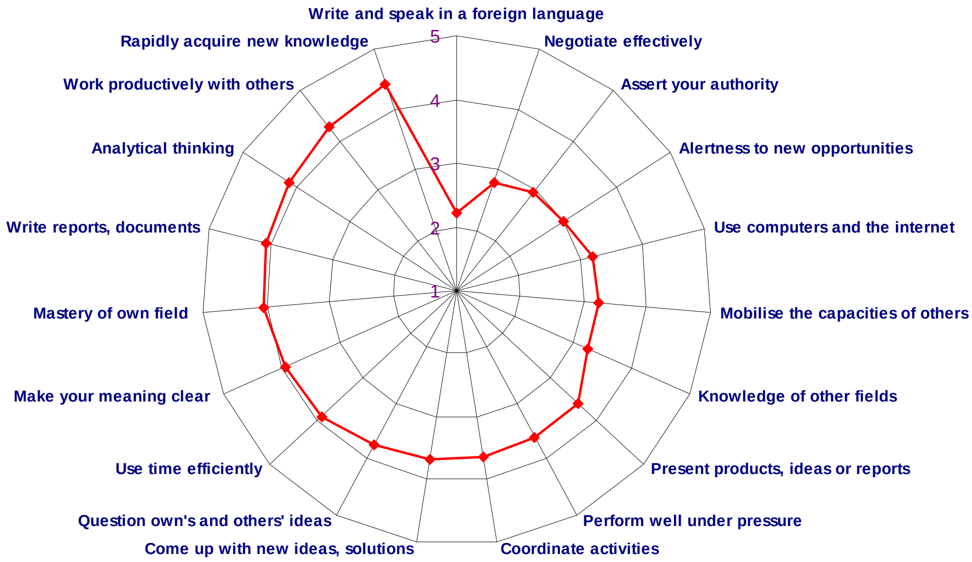
A. "How do you rate your own competence level?"
B. "What is the required level of competence in your current work?"

REFLEX-Spain and PROFLEX questionnaires include an additional question:

C. "What was the contribution of the programme completed to your competence development?"

Answers to the first question may be viewed as a self-assessed measure of the human capital accumulated, in terms of competences, by graduates at the time of the interview. Answers to question B inform us about graduates' view on the human capital requirements of their jobs in terms of competence. Answers to question C contain graduates' evaluation of the value added by their higher education to their human capital equipment in terms of competence. We use the answers to question C to evaluate the output of the education production function in higher education, where diverse combinations of teaching and learning modes are applied within diverse study programmes to students from varied backgrounds and who behave in different ways.

Figure 1.-
Contribution of study programme to competence development. Mean values.



From the list of 19 items, we focus on those competences directly required in order to perform the sequence of activities involved by the innovation process.

Activity	Competence directly required to perform it
Detection of chance	Alertness to new opportunities
Acquisition of new ideas	Ability to come up with new ideas or solutions
Evaluation of ideas	Willingness to question the own and others' ideas
Resource reallocation	Ability to mobilize the capacities of others

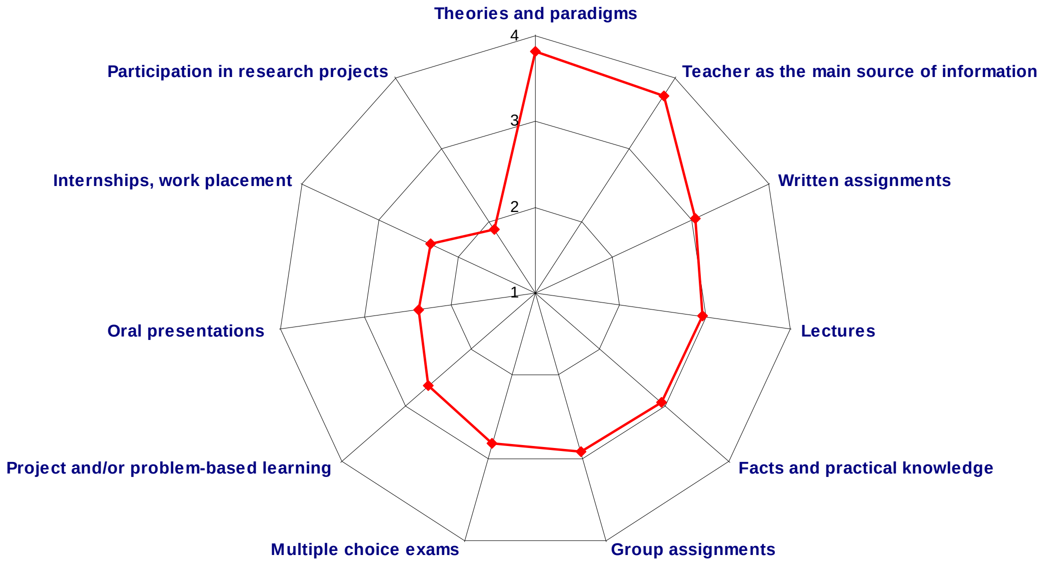
The relationships between input and output are modelled through a set of stochastic frontier production function models where the dependent variables are graduates' views about their development of each CTIs described above. The general model can be written as

$$E_i = f\,(M_{ik}\,,\,C_i\,,\,H_i\,,\,S_i\,,\,A_i) + (u_i - v_i)$$

where E_i expresses educational output in terms of the contribution of higher education to the development of a particular CTI by individual i, M_{ik} is a vector representing the emphasis made on of each one of k teaching-and-learning modes during higher education, C_i stands for the type of programme completed, H_i represents the effort devoted by graduate i to higher education studies, S_i expresses prior educational investments, and A_i contains personal characteristics. The term $(u_i - v_i)$ is an error term with two components: the first one, u_i , is a random noise term normally distributed, and the second one, v_i, is a term of unobserved ability with a positive, half-normal distribution; the distribution of the component reflects the notion that higher education students are selected from the right-hand side tail of the unobserved distribution of natural talent among the population.

Figure 2 shows the average value of Spanish graduates' responses to the question on the emphasis made in diverse teaching and learning modes used during higher education studies. Individual responses enter the models as explanatory variables representing the educational input in the production of competence in higher education.

Figure 2.-
Modes of teaching/learning used in higher education. Mean values.



As students are exposed to the different modes of teaching and learning within diverse study programmes, implying differences in the volume of material resources applied to educate them, the type and length of the programme completed by each graduates should also be included as explanatory variables in the equations. Descriptive statistics of the type and length of study programmes completed by graduates have be

Table 1.-

Length of programmes completed and fields of study (1 digit)

	Mean	Std. Dev.
Short cycle programme	0.43	0.50
Field of study (ref. Education)		
Economics & business	0.19	0.39
Education	0.12	0.32
Technical	0.19	0.40
Health	0.10	0.30
Humanities	0.10	0.30
Law	0.06	0.24
Science	0.11	0.31
Social science	0.11	0.32

To represent the effort devoted by graduates to higher education studies we select the number of study hours per week, a dummy for full-time students, and the answers in Likert scale (1-5) to two questions about graduates doing extra work above that required to pass the exams and about striving for the highest marks during higher education students. Prior educational investments are represented by the marks obtained in secondary education and the educational level achieved by the parents of each graduate. Table 2 summarizes these variables as well as the age and gender of graduates.

Table 2.-

Effort during studies, background and personal characteristics

	Mean	Std. Dev.
Average study hours per week	37.44	16.74
Full time student	0.83	0.38
I did extra work above that required to pass	3.44	1.00
I strived for the highest possible marks	3.79	1.01
Marks in secondary education	2.82	0.92
Father with higher education	0.24	0.43
Mother with higher education	0.17	0.37

Age	30.53	3.32
Woman	0.66	0.47

4. ESTIMATION RESULTS

The development of each CTI has been measured in three ways using the graduates' answers to question C: absolute level of competence development, development relative to individual-mean development of the other three CTIs, and development relative to the individual-mean development of the remaining 15 competences included in Reflex. By expressing the development of a given competence in deviations we mitigate the effects derived from subjective response. The three measures enter as dependent variables in three separate stochastic frontier equations with the explanatory variables, namely Equations 1, 2 and 3. Accordingly, we can estimate the marginal contributions of all input factors to the development of each CTI as well as the effectiveness and specificity of such marginal contributions. The main estimation results have been consolidated in the four panels of Table 3.

Table 3.-
Estimation results for the contribution of higher education to development of CTIs (z-values)
Absolute contribution (Equation 1), relative to other CTIs (Equation 2) and relative to the rest of competences (Equation 3)

	Alertness to new opportunities			Ability to come up with new ideas or solutions			Willingness to question the own and others' ideas			Ability to mobilize the capacities of others		
	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3
Group assignments	0.80	-3.25 *	-0.93	4.54 *	1.15	3.26 *	3.08 *	-1.37	0.84	5.33 *	2.47 *	2.94 *
Lectures	2.22	1.81	1.37	-0.08	-0.98	-1.97	-0.99	-2.16	-1.99	1.06	0.95	0.78
Multiple choice exams	1.38	1.76	1.20	-1.32	-1.48	-2.78 *	-1.18	-1.64	-2.11	1.36	1.48	1.60
Oral presentations by students	2.00	-0.80	-1.48	1.14	-2.73 *	-2.90 *	3.53 *	1.46	0.30	3.86 *	1.04	1.84
Facts and practical knowledge	1.53	-2.62 *	-1.42	4.95 *	2.55	2.56	3.52 *	1.01	1.35	2.09	-2.13	-1.97
Problem-based learning	5.78 *	-0.47	1.38	9.87 *	3.96 *	6.30 *	6.97 *	-0.70	2.15	4.08 *	-2.95 *	-3.27 *
Research projects	4.77 *	1.51	3.14 *	2.55	-1.19	-1.14	1.36	-2.84 *	-1.69	4.72 *	1.57	2.12
Teacher was the main source of information	0.05	0.45	0.12	-0.13	-0.51	-1.05	-0.79	-1.61	-2.03	0.78	1.41	1.47
Teories and concepts	-0.49	-1.66	-2.07	2.34	2.64 *	1.23	3.04 *	3.27 *	2.24	-1.43	-2.95 *	-3.84 *
Internships and work placements	3.65 *	1.40	1.49	1.47	-2.10	-1.35	2.23	-0.02	-0.40	2.60 *	0.18	0.02
Written assignments	0.13	-0.96	-1.45	-0.14	-0.56	-1.79	1.06	1.01	-0.53	0.10	0.16	-0.05
Short cycle programme	-0.53	1.46	1.97	-1.88	0.73	0.17	-4.21	-3.46 *	-3.13 *	0.37	2.53	2.79 *
Field of study (ref. Education)												
Economics and business	3.75 *	3.18 *	1.94	0.75	-0.49	-1.35	-0.10	-1.31	-1.98	-0.36	-2.37	-1.97
Engineering	2.02	0.06	-0.84	3.79 *	4.38 *	1.67	0.91	0.05	-1.40	-1.63	-4.36 *	-4.42 *
Health science	-0.82	1.32	-0.10	-2.44	-0.32	-1.61	-2.46	-0.19	-1.52	-2.34	-1.12	-0.61
Humanities	0.06	1.64	0.45	-1.73	-0.94	-1.55	0.68	3.21 *	1.38	-2.55	-2.49	-2.66 *
Law	1.57	0.90	0.09	0.42	-0.34	-1.28	1.89	2.90 *	0.26	-1.41	-3.54	-3.44 *
Science	0.68	0.02	-0.23	2.42	3.93 *	1.88	0.90	0.92	0.11	-2.22	-3.18 *	-3.76 *
Social science	0.82	-0.87	0.90	0.40	-1.43	1.35	2.40	1.87	4.05 *	1.89	0.56	0.66
Average study hours per week	1.30	0.21	0.17	0.41	-1.46	-1.35	0.46	-1.38	-0.98	1.71	1.97	2.27
Full-time student	-0.24	0.43	-0.62	0.03	0.76	-0.29	-0.57	-1.46	-1.74	-0.62	0.16	0.17
Did extra work about that required to pass	1.09	-0.28	-0.43	2.70 *	-0.02	1.16	2.63 *	-0.07	0.94	0.73	-1.02	-1.17
Strived for the highest marks	1.37	0.52	0.36	1.05	1.39	-0.29	0.73	1.19	-0.17	-0.18	-1.68	-1.57
Marks obtained in secondary education	-2.88 *	-1.75	-3.28 *	-0.57	1.80	-0.30	-0.56	1.26	-0.79	-2.90 *	-1.06	-1.60
Father with tertiary education	-1.34	-1.23	-1.53	-0.16	-0.01	-0.01	-0.01	0.04	-0.04	0.08	1.75	1.60
Mother with tertiary education	1.37	1.06	1.52	0.82	-0.07	0.84	0.93	0.08	1.56	0.62	-0.58	-0.99
Age	1.09	0.34	1.37	0.91	0.20	0.82	1.00	0.78	0.66	-0.48	-1.16	-1.37
Woman	0.95	2.68 *	0.32	-2.24	-1.58	-3.70 *	-3.73 *	-3.56 *	-4.65 *	1.32	2.89 *	3.38 *
Constant	2.67	-0.62	-1.56	2.10	-0.30	-0.37	2.56	1.40	1.11	4.03 *	1.16	0.79
Sample size	*4123*	*4075*	*3905*	*4149*	*4075*	*3917*	*4152*	*4075*	*3922*	*4149*	*4075*	*4075*
Wald chi2	*326.0*	*121.0*	*81.0*	*650.3*	*273.4*	*253.3*	*427.6*	*178.6*	*151.3*	*638.9*	*235.3*	*311.8*
Prob > chi2	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*	*0.000*
Loglikelihood	*-7426*	*-2149*	*-1032*	*-7613*	*-2739*	*-1333*	*-7821*	*-3692*	*-1909*	*-7549*	*-2609*	*-873*

Note: * indicates that $P>|z| < 0.01$

In general, the results show that keeping constant the rest of elements included in the specifications, the panoply of teaching and learning modes deployed during university studies have a substantial influence on the acquisition of CTIs by graduates. Moreover, the influence of teaching and learning modes shows a characteristic pattern regarding each CTIs considered. Comparatively, the effects of the other input factors included in the models are weaker than those corresponding to the modes of teaching and learning used at university.

The contribution of higher education to the development of the competence *Alertness to new opportunities*, required to realize the chances of innovate, depends in absolute terms (Equation 1) on the use of problem-based learning, participation in research projects and the provision of internships and work-placements during university education. However, emphasizing group assignments and facts and practical knowledge contribute relatively less to the development of this competence than to the development of the other CTIs (Equation 2). The participation in research projects emerges as the most effective way to develop the *Alertness to new opportunities* expressed in relative terms to the mean development of the 15 competences not directly related to innovation (Equation 3).

Graduates' development of the competence *Ability to come up with new ideas and solutions* depends positively on the use of problem-based learning both in absolute and in relative terms, indicating that this method appears to contribute specifically to the acquisition of the competence. Group assignments also contribute to the development of the competence in absolute terms (Equation 1) and in relative terms regarding the mean of the competences not related to innovation (Equation 3), but no so regarding the mean of the other CTIs (Equation 2) The emphasis on facts and practical knowledge promotes the development of the competence in absolute terms only. Oral presentations show negative contributions in relative terms, suggesting that this mode of teaching/learning is less appropriate to develop this competence than to develop other competences. Multiple-choice exams display a negative contribution to the development of the *Ability to come up with new ideas* compared with their contribution to the mean development of competences not directly related to innovation, confirming that the assessment based on suggested answers does not promote the innovative capacities of graduates.

The acquisition of the competence *Willingness to question ideas* depends positively, in absolute terms (Equation 1), on the use of a number of teaching and learning modes: problem-based learning, oral presentations, group assignments, facts and practical knowledge and theories and concepts. Apparently, the development of the competence behind the evaluation of ideas requires the combination of several methods in higher education. Nonetheless, theories and concepts contribute to develop this competence more than they do to develop the other CTIs, while the contrary holds for the participation in research projects (Equation 2). Additionally, no method shows a higher specific contribution to the development of the *Willingness to question ideas* compared to the mean contribution to the development of competences not directly related to innovation (Equation 3).

The development of the *Ability to mobilize the capacities of others* depends positively on the use of group assignments both in absolute and relative terms. In absolute terms, it depends as well on the participation in research projects, and on the use of problem-based learning, oral presentations, and theories and concepts. However, both problem-based learning and theories and concepts show negative coefficients in relative terms regarding the development of the rest of competences, suggesting that these methods are not particularly effective to specifically develop the *Ability to mobilize the capacities of others*.

The estimation of stochastic frontier equations allows us to test whether or not the development of CTIs in higher education is contingent on the natural ability of individuals. The relevant tests, reported in Table 4, do not support such contingency: the values of the Chibar2 test with 1 degree of freedom lead to reject in all cases the presence of significant effects on the development of CTIs due to unobservable heterogeneity related to natural ability. Consequently, there is not evidence to support the notion that some individuals are naturally more efficient than others in the acquisition of CTIs during their university years.

Table 4.-
Estimation results for innefficiency terms in stochastic frontier equations for the contribution of higher education to competence development
Absolute contribution (Equation 1), relative to other CTIs (Equation 2) and relative to the rest of competences (Equation 3)

	Alertness to new opportunities			Ability to come up with new ideas or solutions			Willingness to question the own and others' ideas			Ability to mobilize the capacities of others		
	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3	Equation 1	Equation 2	Equation 3
Inefficiency (lambda)												
coefficient	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01
standard error	0.32	0.07	0.11	0.57	0.08	0.07	0.64	0.10	0.08	0.38	0.09	0.07
chibar2(1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
prob>chibar2	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

In order to check the robustness of the results obtained so far, and taken into account that the inefficiency terms in the stochastic frontier equations are no significant, the analysis is replicated using variance components models to take advantage of the clustered nature of data according to the programme completed. By combining the type of credential obtained, determined by the length of the programme, with the field of study it belongs to, we define 35 groups of graduates and estimate the following equation

$$E_{ij} = g\ (\ M_{ijk}\ ,\ H_{ij}\ ,\ S_{ij}\ ,\ A_{ij}) + (u_j+v_{ij})$$

where E_{ij} expresses educational output in terms of the contribution of higher education to the development of a particular CTI by individual i in programme j, M_{ijk} is a vector representing the emphasis made on of each one of k teaching-and-learning modes during higher education, H_{ij} represents the effort devoted by graduate i to programme j, S_{ij} expresses prior educational investments, and A_{ij} contains personal characteristics. The error term (u_j+v_{ij}) has two independent, normally distributed components: u_j represents noise emerging from the programme clusters whereas v_{ij} stands for individual noise. The estimation results, shown in Table 5, indicate that the marginal effects of teaching and learning modes are very close to those obtained under the stochastic frontier model. Additionally, estimates of intra-group correlations reveal that the influence of the programme completed in the development of some of the CTIs is substantial, particularly regarding the *Ability to come up with new ideas or solutions* and, to a lower extend, the *Willingness to question the own and others ideas*.

Table 5.-
Estimation results for absolute contribution of higher education to development of CTIs. Variance components model by type of programme completed

	Alertness to new opportunities		Ability to come up with new ideas or solutions		Willingness to question own's and other ideas		Ability to mobilizef the capacities of others	
	z-stat	P>|z|	z-stat	P>|z|	z-stat	P>|z|	z-stat	P>|z|
Group assignments	0.99	0.321	4.33	0.000 ***	3.26	0.001 ***	5.96	0.000 ***
Lectures	2.05	0.040 **	-0.22	0.824	-1.14	0.252	0.99	0.321
Multiple choice exams	1.58	0.113	0.13	0.900	-0.81	0.419	1.79	0.073 *
Oral presentations by students	1.88	0.061 *	0.95	0.343	3.26	0.001 ***	3.73	0.000 ***
Facts and practical knowledge	1.12	0.264	5.09	0.000 ***	3.68	0.000 ***	1.89	0.059 *
Project and/or problem-based learning	6.10	0.000 ***	9.48	0.000 ***	6.83	0.000 ***	3.84	0.000 ***
Participation in research projects	4.87	0.000 ***	3.40	0.001 ***	1.93	0.054 *	5.33	0.000 ***
Teacher as the main source of information	0.18	0.859	0.16	0.869	-0.51	0.608	0.91	0.364
Theories and paradigms	-0.13	0.895	1.56	0.120	2.83	0.005 ***	-1.11	0.266
Internships, work placement	3.32	0.001 ***	0.80	0.425	1.89	0.059 *	2.82	0.005 ***
Written assignments	0.09	0.926	0.69	0.488	1.45	0.147	0.39	0.695
Average study hours	1.39	0.166	-0.01	0.993	0.15	0.879	1.14	0.255
Full time student	-0.14	0.889	-0.23	0.815	-0.82	0.412	-0.49	0.626
Did extra work	1.05	0.295	2.68	0.007 ***	2.79	0.005 ***	0.80	0.425
Strived for highest marks	1.15	0.248	0.92	0.359	0.32	0.752	-0.34	0.733
Secondary marks	-2.68	0.007 ***	-0.82	0.414	-0.55	0.581	-3.28	0.001 ***
Father higher education	-1.37	0.170	-0.16	0.874	0.04	0.972	0.14	0.887
Mother higher education	2.13	0.033 **	1.81	0.070 *	1.20	0.228	1.06	0.288
Age	1.29	0.197	1.45	0.148	1.52	0.129	-0.52	0.604
Woman	1.01	0.310	-1.84	0.066 *	-3.66	0.000 ***	1.65	0.099 *
Constant	3.12	0.002 ***	2.85	0.004 ***	3.29	0.001 ***	4.28	0.000 ***
Variance components								
σ^2 (programmes) & s.e.	0.021 *(0.010)*		0.211 *(0.066)*		0.118 *(0.043)*		0.023 *(0.012)*	
σ^2 (individuals) & s.e.	2.148 *(0.048)*		2.236 *(0.050)*		2.516 *(0.056)*		2.227 *(0.050)*	
Within groups correlation	1.0%		8.6%		4.5%		1.0%	
Within groups correlation empty model	*1.3%*		*9.8%*		*5.4%*		*4.8%*	
Number of individuals	*4031*		*4056*		*4058*		*4055*	
Number of groups by programme	*35*		*35*		*35*		*35*	
Log restricted likelihood	*-7321*		*-7474*		*-7704*		*-7438*	

Note: *** indicates that P>|z| < 0.01, ** indicates that P>|z| < 0.05 and * indicates that P>|z| <0.1

5. CONCLUDING REMARKS

We have analyzed the influence of the teaching and learning modes used in higher education on the acquisition by graduates of diverse competences required to innovate. The analysis, carried out in a framework of educational production, identify the effects of the teaching and learning methods and those of the other input factors, either educational or of human capital, than enter in the production function of higher education. The estimation of stochastic frontier equations permits to control for a possible influence of unobserved heterogeneity among individuals on the outcomes of higher education expressed in terms of the acquisition of the competences required to innovate productively in the workplace.

The results point out that the panoply of teaching and learning modes deployed during higher education studies is a key determinant of individual progress regarding the development of competences required to innovate when the other elements involved are kept constant. Moreover, the results indicate that the influence of teaching and learning modes on the development of each competence considered has a characteristic pattern. Overall, the analysis suggests that the use during higher education studies of proactive teaching and learning modes promotes differentially the acquisition of CTIs. Project or problem-based learning and with group assignments appear as the single methods with stronger influence in the development of CTIs, which suggests that collaboration with other people improves the acquisition of innovation capabilities. It is possible, besides, to identify the most effective mode to develop each one of the competences required by the innovation process. Accordingly, the development of Alertness to new opportunities depends on the participation in research projects, the Ability to come up with new ideas or solutions is developed specifically by problem-based learning, the Willingness to question ideas is promoted by the emphasis in theories and concepts, and the Ability to mobilize the capacities of others is improved specifically using group assignments. Additionally, estimation results also show that the effects of the other factor inputs in the development of the competences considered are much weaker than those corresponding to the teaching and learning modes. Finally, the analysis did not find evidence of unobserved heterogeneity influencing the acquisition in higher education of those competences required to innovate at the workplace.

Nevertheless, it is worth noting that the implementation of changes or reforms in higher education studies can not be based only in estimations of marginal effects of diverse input factors included a suitable education production function. Researchers and higher education institutions need to learn more about possible trade-off between diverse type of resources involved, on the one hand, and between the outcomes obtained, on the other hand, in their production process. Moreover, the resources should be examined in terms of their relative costs and the results in terms of their relative values to individuals and to society at large. To obtain that type of knowledge would require deeper analyses using preferably longitudinal data sets at the appropriate level of aggregation. Collaboration between researchers and institutions is crucial to improve knowledge about the relationships between the resources allocated to higher education systems and the private and social outcomes generated through them.

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