THE DURATION OF THE PHD AT SPAIN FROM A STOCHASTIC FRONTIER PERSPECTIVE: IS IT REALLY A TRICK-OR-TREAT ISSUE?

Marta Martínez Matute

Bank of Spain

marta.martinez@bde.es

Alcalá 48, 28014

Madrid (España)

Tel.: 913385415

ABSTRACT

The duration of the PhD is a relevant issue which influences the career prospects of the student during the rest of his life. It is also important because there are different resources, such as public expenditure or the reputation of the research centre or university where it has been done, which depends on this question. This paper examines the effect of different characteristics of Spanish PhD students on the duration of their PhD thesis. Previous evidence has found that individual characteristics as much as public funding and the existence of a supervisor affects the duration of the studies but also the prospective career of the PhD student. We assume that the duration of the PhD depends on an efficiency issue which could be analyzed from a new methodological point of view. To that aim, this paper proposes a stochastic frontier model to measure the lost of efficiency of some students due to different factors and which could be the cause that contributes to increase their PhD duration at Spain. We estimate the frontier model for the years 2006 and 2009, which also let us to analyze if the economic crisis has affected the influence of the variables on the PhD duration.

Keywords: PhD duration, efficiency of education, stochastic frontiers, postgraduate studies.

JEL codes: I21, I23

1. INTRODUCTION

The relevance of the analysis of PhD duration is associated with two main issues. First of all, it is a potential instrument to measure the research efficiency of a university department. As it is assumed by Booth and Satchell (1995), inefficient departments are related to longer average time to completion and higher withdrawal rates. Time-to-completion a PhD became a sensible way to describe the scientific achievement of a PhD student; empirical research indicates that a better student may be able to finish it more rapidly than other one (Robin, 2002)[1]. Secondly, every year there is a considerable public expenditure in order to finance the research activity of a high amount of PhD students by scholarships, studentships, grants and other types of funding. The number of students who defend a PhD thesis at Spain is growing every year[2] and, although the public expenditure on R&D has decreased over the last years as a consequence of the fiscal austerity measures, the expenses on doctoral research continue representing a great amount of public expenses[3]. It is important to control the efficiency of that expenditure, and not only the quantity. Therefore, it is also essential to study if the effect of the public funding contributes to increase the research level of the doctoral programs of Spanish universities by the way of reducing the duration of the PhD. But it is also important to note if there are other variables, as well as the doctoral funding, which also affect the length of the period, such as some personal characteristics (gender, age, nationality) or the educational background (type of doctoral program, number of years employed in their graduate studies, tasks of teaching or researching assistant, the possibility of application of the research), and the way they do it.

Previous literature has found evidence about this question. From the classical paper of Breneman (1976), which firstly applied an economic model to the PhD production process in order to discern the differences in the mean time to degree and in student attrition, some papers have studied this process by different methodologies and databases. Most of them defend the idea that there are several factors affecting the duration of different educational programs. This

[1] There are other ways to prove the scientific achievement, such as the impact or the number of publications (Levin and Stephan, 1991). However, for measuring the PhD efficiency, we think that the duration could be the most appropriate variable because of two main reasons: there is a standard quality of the PhD thesis lectured, as we explain afterwards, and not all the PhD students try to publish in academic journals and continue their career researching, but this not means that their thesis were not better than others.

[2] In 2011, there have been 9487 lectures of PhDs, just an 8.5% more than the previous year (MECD, 2012).

[3] Only the University Professor Training program (which in Spanish is known as *Formación del Profesorado Universitario*, or by its initials as *FPU* program) estimates a budget of about 65,513,424 € for the 2013 call. In the 2012 call, it was of 72,457,684 €. In addition, there are also other studentships for doing a PhD funded with public expenditure. In the third section of this paper, we would go deeply into this question.

question has been studied specially from the economics discipline because it has many implications for the economic policy.

There are individual characteristics and other factors, such as the public funding or the supervision, which affect the duration of a PhD and also the academic prospective of the student. However, while other papers focused on the expected completion rates of the students, it is important to analyze the duration of the PhD such as a production process which could minimize costs, where there are some inputs that entry (such as the labor of the student) and a product, the PhD thesis, turns out in the future. This question implies that there are some PhDs made with less costs than others and also there are some PhDs finished more rapidly. Assuming the existence of a standard minimum quality required to finish a PhD the study[4], the analysis of the PhD duration allow us to apply the efficiency methodology to the field of education, through measuring the duration from a stochastic frontier perspective. The research of Van Ours and Ridder (2000) provides some evidence about the effect of different factors on the failure and completion rates of graduate students in economics in Netherlands. They found an indicator of the research productivity of the supervisor as an important determinant of the dropout rates.

At the postgraduate level, several studies have already provided evidence supporting the idea that there are many individual characteristics affecting the expected duration of the PhD studies through the possibility of completion or withdrawal. The academic discipline, the mode of study (full-time versus part-time), the age of the student and the country of residence influence the duration of a PhD. Park (2005) proved that students from science-based areas of research are more likely to finish a PhD than those from humanities and social-sciences. At the same time, full-time students and older students (more than 27 years old) are more likely to complete their PhD studies than others (Wright and Cochrane, 2000). International students also provide empirical evidence to affirm that they are usually quickly than their national colleagues.

However, not only the individual characteristics of the student affect the PhD duration. The effect of supervision on the PhD duration has also influence it and the academic career. Robin (2002) showed that there is a strongly correlation of the supervision on the duration of the PhD, the number and quality of publications and job outcomes after completing the PhD. To that aim, he studied, on one hand, the differences in the scientific achievement of the PhD and, on the other hand, the returns to the PhD holder.

Public funding has also a great influence in the decision of finishing a PhD and in the duration. The classical work of Booth and Satchell (1995) focused on this question. With a database of British graduates for the year 1986, they observed a great variation of completion

[4] Otherwise, the PhD thesis could not be finished or would be negatively evaluated by the tribunal.

rates along students depending on the disciplines, gender and employment status while their PhD period. They found that the ability (measured by a first-class degree) has an insignificant effect on completion form males, but not for women, while the type of PhD program (part-time or full-time) and the employment has a negative effect only on male completion rates. Ehrenberg y Mavros (1995) also proved that the mean duration of time-to-completion and dropout are sensitive to type of financial support of the student. Fellowships or research studentships have higher completion rates and shorter times to completion than teaching positions, tuition waivers or self-funding.

The application of the methodology of Stochastic Frontier Analysis (SFA) to the field of education has some empirical difficulties, as is shown by Pereira and Moreira (2007). On one hand, the definition of "output" in the education process could be controversial. On the other, there are many factors which influence the student and that have to be incorporated in the model, and it is sometimes quite difficult to have good measures of them.

Our paper differs from those ones in some points. PhD period allow us to measure the efficiency in terms of duration because the output (the PhD thesis) is similar depending on some characteristics. We could assume that the less the duration of a PhD thesis is, the more efficient is than other with the same characteristics. Because of that, the objective of this paper is to measure the level of efficiency in the duration of a PhD thesis. As a result, the differences in efficiency based on the type of funding, the research area or the personal characteristics of the student could bring us an idea of where to support the research policy.

Finally, there is no evidence for the Spanish case yet. That is the reason why we propose this paper focused on the efficiency perspective for the Spanish case. In the case of Spain, the existence of a database with information about doctors who has already defended their PhD in 2006 and in 2009 contributes to provide some brightness on this question and, in addition, it let us to know if there has been any change in the results or behavior patterns caused by the economic crisis.

The remainder of this paper is set out as follows. In Section 2, we describe the Spanish PhD system and the main studentships and grants to funding it. In Section 3, we describe the dataset used in this paper and the methodology of stochastic frontiers. In Section 4 we proposed the estimation specification of the model and we analyze the results obtained. Finally, in Section 5 we present the main conclusions of the paper.

2. THE PHD STUDIES SYSTEM AT SPAIN AND ITS FUNDING

After finishing the graduate studies at Spain, the student could also choose to begin a postgraduate program. The PhD program at Spain has two different parts: the training part, which is the first one, and the research part, which comes after the first. The research part consists basically in doing the PhD thesis.

Before 2007, a graduate student could immediately begin a PhD program. The training part of the PhD program extended one or two years, depending on the type of the program and the capability of the student. It consisted in the studying of several advanced subjects and the presentation of a predoctoral thesis. Once the student passed this part, he received the Advanced Studies Diploma or the Research Sufficiency condition, and he could immediately begin with the PhD thesis.

In 2007, the legislation changed[5] in order to unify the education programs at Spain with the European Union according to the Bolonia Process and the creation of the European Higher Education Area (EHEA). Currently, a student that wants to do the PhD thesis has to study previously an official Master´s program which must be regulated according with the new educational framework. The new Master´s program is the training part of the PhD program. Thus, after finishing the Master´s program[6] and the lecture of the Master´s thesis (which is similar to the predoctoral thesis of the old program), the postgraduate student could begin directly with the PhD thesis by enrolling in the doctoral program. However, there is an exception to consider. The students who had begun an old doctoral program could start their research part of the new doctoral program if they have already reached the research sufficiency of their old training programs. If not, they have to study a current Master´s program. We could observe these situations in the Figure 1.

Although the number of students enrolled in a PhD program has decreased over the last years (except in the 2010/2011 year, when it increased from the previous year) the number of PhD thesis registered has increased progressively. This trend explains that the indicator of the PhD lectures[7], which is the number of students enrolled in a postgraduate program over the

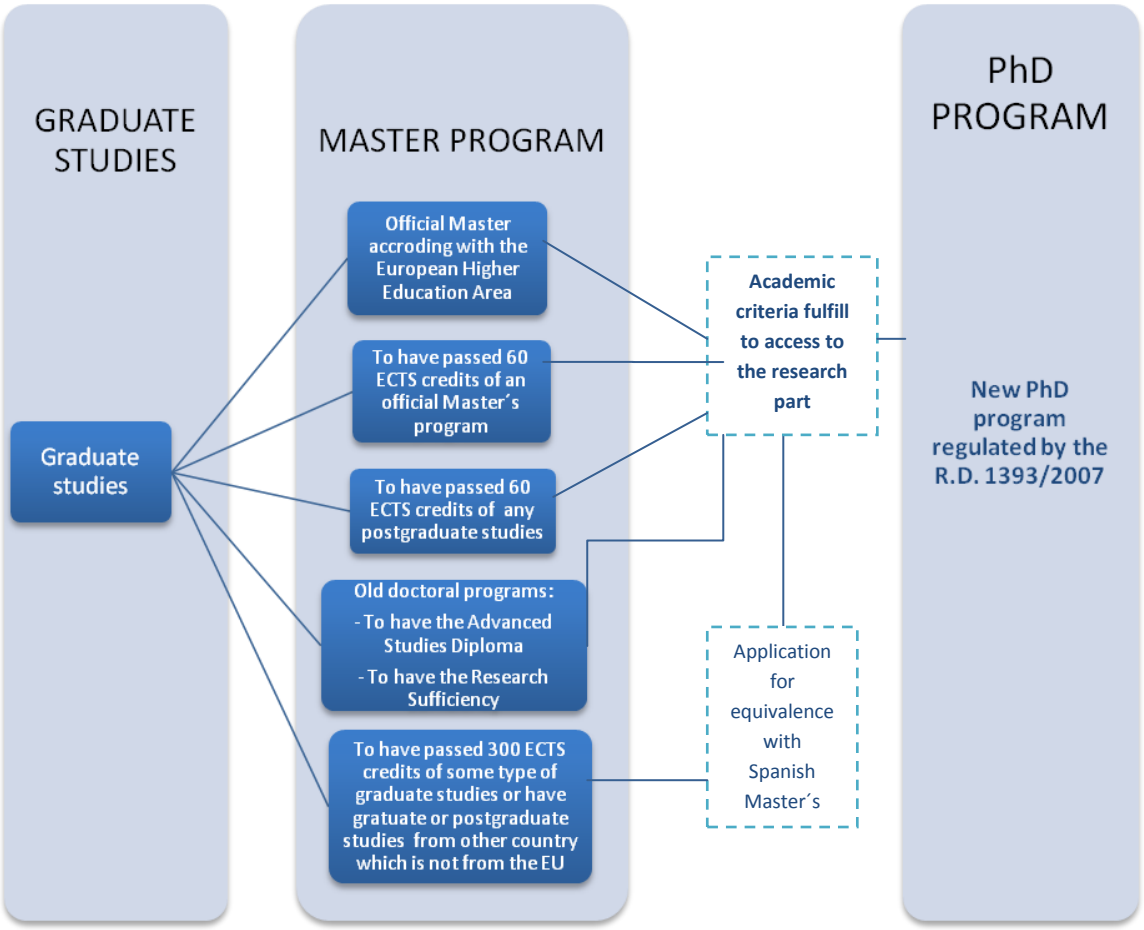
[5] Through Organic Law 4/2007, of 12th April, to regulate the new University system, and the Royal Decree-Law 1393/2007 of 29th October, which establish the new official higher education plans.

[6] However, there are still different types of Master´s program. The condition to access to the research part (the pure PhD program) is to have passed 60 ECTS credits. If the Master is longer (with a charge of 120 credits) or from an old plan, the student could access only if the first condition is fulfill.

[7] It is similar to an indicator (I.20) recommended by the CRUE (2012) to measure the efficiency of the PhD programs at Spain. In their case, the measure the number of students enrolled in Master´s program over the number of PhD thesis registered only in public universities. We think that it could be improved by capturing the number of students enrolled exactly in PhD programs than Master´s program, because there are many Master´s students that do not have the intention to continue with a PhD while probably all the students enrolled in the PhD program would like to finish their PhD thesis.

number of PhD lectures at Spain, has been decreasing during the last decade (1999-2010), as we could see in the Table 1.

FIGURE 1: Ways to access to a current PhD program at Spain



Source: own compilation

However, recently, this indicator has grown after all, fact that could be explained by the change in the decreasing trend in the number of PhD students. Currently, there are nearly 8 students enrolled in a PhD program over every PhD thesis registered in the same academic year.

The composition of the areas of the PhD thesis registered at Spain is heterogeneous. Most of the PhD thesis registered are from the Health and Experimental Sciences area of research (around de 42% of the thesis of the 2009/2010 academic year), followed by the thesis of Social Sciences and Law (23% in the same year), then the Technology and Engineering area (16%) and finally the Humanities thesis (which only represents a 14% of all the thesis registered)[8].

[8] There is a "not distributable" category for the rest PhDs which do not have an area related.

TABLE 1: Number of students and PhD thesis by academic year

ACADEMIC YEAR	Students of a PhD program					PhD lectures	PhD lectures indicator
	Total	Men	Women	Public University	Private University		
1999/2000	64293	32025	32268	61648	2645	6408	**10.033**
2000/2001	62530	30817	31713	60166	2364	6380	**9.801**
2001/2002	65690	32197	33493	62873	2817	6936	**9.471**
2002/2003	72973	35737	37236	69693	3280	7467	**9.773**
2003/2004	77439	38262	39177	73740	3699	8176	**9.471**
2004/2005	76251	37194	39057	72484	3767	6902	**11.048**
2005/2006	77056	37758	39298	73002	4054	7159	**10.763**
2006/2007	72741	35059	37682	68673	4068	7150	**10.174**
2007/2008	66973	31949	35024	63225	3748	7302	**9.172**
2008/2009	67000	32519	34481	63200	3800	7915	**8.465**
2009/2010	63466	30557	32909	58994	4472	8596	**7.383**
2010/2011	68865	33749	35116	64492	4373	8915	**7.725**

Source: Higher Education Statistic at Spain (Spanish Statistical Office)

Note: The PhD indicator measures the number of students enrolled in a PhD program by every PhD lecture of the same academic year.

At the same time, we could consider the composition of PhD students by age. The group of age more representative in a PhD program is the older than 40 years old one (a 24.6% of the total) in the 2009/2010 academic year, while the group between 30 and 35 years is also very important (24.3%). Students between 35 and 40 years are a 14.2% of the total. This is an interesting issue, because it indicates that the PhD program is mostly coursed by people with more than 30 years all (64%). People before 29 years old only represent a 36%. Another interesting point is that there is a 4% of the total formed by students with less than 24 years old, and a 9% of the total if we consider students with less than 25 years old, which seems to be that they begin these studies very younger and finished the studies before quickly.

The public funding of the PhD programs could be diverse. At Spain there are different types of grants and studentship that help students to carry out the PhD program during a period of time. Spanish Government usually approves a National Scientific and Technical Research Plan every four years, which is composed by the main lines for the public support of the research activities at Spain. In the last of these Plans, the one for the period 2013-2016, there has being included the Talent and Employability Promotion Program. This program is composed by three subprograms with different objectives: the education and training research activities (Training Subprogram), the incorporation to the scientific and technical workforce (Incorporation Subprogram) and the mobility activities (Mobility Subprogram).

The first one, the Training Subprogram, is entirely dedicated to finance research activities by the granting of different awards and scholarships to predoctoral and postdoctoral researchers, mainly by contracts with a duration of four years for doing the PhD in a university department or in a research centre. In the 2013 wave, there are three main awards from this subprogram dedicated to PhD students and they have their own budget estimated:

- The University Professor Training program (which is known in Spanish as *Formación del Profesorado Universitario* or *FPU* program), with a total funding of 65,513,424 €.
- The Researching Personnel Training program (which is known in Spanish as *Formación del Personal Investigador* or *FPI* program) with 78,866,000 € dedicated to it and another 600,000 € to pay doctoral fees.
- The Severo Ochoa predoctoral contracts, with a budget of 6,712,000 €.

In the Mobility Subprogram there is also another scholarship to promote the mobility to the PhD students: the 2013 predoctoral mobility grants for visiting shortly other research centres in Spain or abroad (usually called *Programa de Estancias Breves*), which has a budget of 7,000,000 €.

Even though PhD could be carried out with public studentships and grants, there are other possibilities for financing a PhD. With the database we employ in this paper[9], in the wave referred to the 2006 we have fourteen different categories of ways to finance a PhD, while in the 2009 wave there are only nine categories. In the Table 2, we observe the distribution of PhD students by the type of funding that they consider as mainly. The main way to obtain a funding aid for doing the PhD is a public studentship, but it is also very important the number of students who worked as a professor or research assistants (their salaries also come from public expenditure in the commonly case they work for public universities or research centres). There are a 25.2% in 2006 and a 16.76% in 2009 of students who work on other occupations, whichever they were part-time or full-time jobs.

Once we have described the PhD system at Spain and observed the great amount of public studentships expended in the funding of PhD students, our empirical strategy would let us to know if there are any differences in the duration of the PhD period between students who finance themselves or who use public funding, and even the level of inefficiency of anyone of them.

[9] We would explain the database framework in the following Section.

TABLE 2: Main ways to finance a PhD program at Spain*

Type of funding	2006		2009	
	PhD students	%	PhD students	%
Public administration studentship**	3861	30.58	1416	34.34
Studenship from university where does the phd	967	7.66	181	4.39
Enterprise studentship	157	1.24		
Private non-profit organization	269	2.13		
International studentship	95	0.75	50	1.21
Work as research and professor assitant	1381	10.94	950	23.04
Other occupation	3182	25.20	691	16.76
Refund subsidy by employer	45	0.36	28	0.68
Loan. personal savings and familiar support	2114	16.74	627	15.21
Other form	554	4.39	180	4.37
TOTAL	**12625**	**100**	**4123**	**100**

Source: Spanish Survey on Human Resources in Science and Technology (HRST)
Notes: *We have gathered different categories of funding from the original Survey of 2006 in order to homogenize the table with the 2009 Survey. ***Public Administration Studentships* include the predoctoral awards and studentships explained previously as part of the National Scientific and Technical Research Plan in these cases for the 2006 and 2009 years.

3. DATA AND METHODOLOGY

3.1. Dataset and descriptive analysis

We used microdata from the Spanish Survey on Human Resources in Science and Technology (HRST). It is a new survey provided by the Spanish Statistical Institute and it contains information about Spanish PhD holders in the years 2006 and 2009. Variables of 2006 are different from those in 2009[10], but they both include information about doctorate holders, the PhD thesis, their educational background, and their post-doctorate careers and international mobility experience[11].

It is important to point out some questions about the data employed in this paper. Firstly, in contrast with other surveys used in the PhD duration literature, we do not have information about the people who begin a PhD program and withdraw; we only have successful students who complete their PhD and who are PhD holders living in Spain in the previous year.

[10] 2006 survey includes more information about the type of funding of the studentship during the PhD instead of variables about the family background and region where born of 2009 survey.
[11] Dueñas et al. (2013) use the survey of 2009 to provide information about the returns obtained from doctorate holders who move away to another country after the PhD lecture.

Secondly, the duration of the PhD is measure by the difference between the moment when the student first enrolled in the program and the moment which he defends and he has the lecture of the PhD thesis. Therefore, there could be some students that only have applied for the PhD program once they have just finished their PhD thesis or who have practically finished it without being enrolled yet. That is why we could find some PhD students who were only enrolled during some months (usually less than a year). In our 2006 data, there are seven students who have completed their PhD in less than a year, and who could probably be in this group of students described before[12].

As is was already mentioned, the duration of the PhD is shown in the survey in two variables, one for the number of years and another one for the number of months during the last year. Consequently, we have defined a new variable which is the sum of the both previous variables, and we have expressed the total duration in two dimensions: years and months. The new variables express the duration of the PhD in months (named *DURMES*) and also in years (named *DURANO*) equivalently. As we see in the Kernel density estimation graphs of the Appendix A.1 (for 2006) and A.2 (for 2009), the distribution of the duration is different by groups but mostly varies between 4 and 6 years. The average duration was 5.96 years long in 2006 and 5.90 years long in 2009. Table 3 shows the mean statistic of the duration of the PhD by different characteristics, measure both in years and months and for 2006 and 2009.

We observe that the average duration is lower for the case of women and also for students who do not born at Spain. Considering the academic scope, we found that the students from sciences and engineering finished faster their PhD, which is also according to the previous evidence (Park, 2005).

Funding factors confirm the previous evidence shown in the literature about the students who have a studentship, whatever it came from, that finish their studies more rapidly than others. But we have to consider that this idea could have a selection problem because the kind of students who have a studentship could also be more efficient than others because they have passed a previous draft or recruitment process (usually based on their better academic background) in order to obtain it.

[12] However, we do not have any reason to drop them from the sample, because we do not really know whatever its short duration is caused by their ability or by other factors.

TABLE 3: Average duration in years and months by different characteristics

CHARACTERISTICS	2006		2009	
	In years	In months	In years	In months
Genre				
Males	**6.0236**	72.2778	**5.9051**	70.8607
Females	**5.8909**	70.6881	**5.8920**	70.7041
Academic discipline				
Sciences	**5.3893**	64.6686	**5.3180**	63.8160
Engineering	**5.5750**	66.8929	**5.4576**	65.4913
Medcine	**5.9707**	71.6425	**5.8551**	70.2610
Agriculture	**5.4108**	64.9300	**5.5597**	66.7164
Social Sciences	**6.3604**	76.3231	**6.4399**	77.2783
Humanities	**6.9887**	83.8613	**6.8487**	82.1848
Type of funding				
Public administration studentship	**5.1638**	61.9661	**5.0299**	60.3591
Other Spanish institution and enterprises	**5.2031**	62.4359	**5.1726**	62.0713
International studentship	**5.5325**	66.3895	**5.1350**	61.6200
Working as research and professor assitant	**5.8750**	70.4937	**6.3520**	76.2242
Other occupation	**6.9794**	83.7429	**6.6452**	79.7424
Refund subsidy by employer	**5.9704**	71.6444	**5.3899**	64.6786
Loan, personal savings and familiar support	**6.2831**	75.3930	**6.2345**	74.8134
Other type of funding	**6.6898**	80.2780	**6.3616**	76.3389
Type of research				
Pure or fundamental research	**6.1159**	73.3907	**5.8441**	70.1292
Applied research	**5.9600**	71.5165	**5.8880**	70.6562
Experimental development	**5.5043**	66.0438	**5.5003**	66.0039
Country where born*				
Spain	**6.1385**	73.6625	**6.2975**	75.5701
Abroad	**5.9577**	71.4885	**5.8887**	70.6643
Age when survey (over 2006/2009)				
Less than 30	**4.4479**	53.3753	**3.7083**	44.5000
Between 31 and 40	**5.4971**	65.9599	**5.1443**	61.7315
Between 41 and 50	**6.3472**	76.1626	**6.0247**	72.2964
Between 51 and 60	**7.5978**	91.1741	**7.0722**	84.8668
More tan 61	**8.2404**	98.8842	**8.5372**	102.4468
TOTAL	**5.9636**	71.5589	**5.8993**	70.7917

Source: Spanish Survey on Human Resources in Science and Technology (HRST)
Note: *We only take into account the country were the student was born, because the nationality could have changed during the period of the PhD.

We do not appreciate significant differences in the duration between 2006 and 2009, which is consequent with the database, because only a 1.35 % of the people surveyed in 2009 has finished the PhD during the period considered between both years, and the differences could be based more likely on the differences of the sample representation. Nevertheless, it is important to consider both surveys because some variables may be appraised or concern the student by different ways.

Finally, it is important to remark that there is a considerable significant reduction of the duration by the age of the person. If we observe the Table 3, the younger the student is at the moment of the survey, the faster it takes him to finish the PhD. This means that currently, the average PhD duration is shorter than in the past decades.

3.2. Methodological strategy: stochastic frontiers model

A frontier production function, or a cost function, represents the ideal maximum output attainable given a set of inputs, or the minimum cost of producing the output given the prices of the inputs, respectively (Greene, 1993). Stochastic frontier analysis (SFA) was proposed by Aigner et al. (1977) and Meeusen and Van der Broeck (1977). Their idea was to introduce a double component on the error term: one for measuring technical inefficiency and another one for random error component. That way, they capture the deviations from the production frontier that might not be completely desired by the firm. Kumbhakar and Lovell (2000) describe the SFA approach extensively.

The stochastic frontier model could be represented from the following equation:

$$q_i = f(\boldsymbol{x}_i; \boldsymbol{\beta}) \cdot e^{v_i} \cdot TE_i, \tag{1}$$

where y_i is the output of the firm *i*, $f(x_i; \beta)$ is the deterministic production function composed by a vector $\boldsymbol{x}_i$ of K inputs and a vector $\boldsymbol{\beta}$ of K+1 parameters. The term e^{v_i} embodies the random errors of every firm, and TE_i shows the technical inefficiency of the firm *I*, so that the firm would obtain the maximum feasible output only if $TE_i = 1$, because:

$$TE_i = \frac{q_i}{\exp(\boldsymbol{x}_i \cdot \boldsymbol{\beta} + v_i)} = \frac{\exp(\boldsymbol{x}_i \cdot \boldsymbol{\beta} + v_i - u_i)}{\exp(\boldsymbol{x}_i \cdot \boldsymbol{\beta} + v_i)} = \exp(-u_i). \tag{2}$$

When $0 < TE_i < 1$, it shows the shortfall of observed output from the frontier (Pereira and Moreira, 2007). As Coelli et al. (2005) suggests, this function measures the output of the *i*-the firm compared to the output obtained by a fully-efficient firm using the same input vector. Before predicting the technical efficiency, $TE_{i,}$, it has to be estimated the parameters of the stochastic production frontier model.

Reformulating the equation (1) and expressing the output in logarithms, we obtain the following:

$$\ln q_i = \alpha + \boldsymbol{\beta} \cdot \boldsymbol{x}_i + v_i - u_i \tag{3}$$

where v_i is assumed to be independent from u_i. The equation could be estimated by maximum likelihood.

As it was shown by Greene (1991), the estimation of a production function is based on the objective of measuring inefficiency by the analysis of the residuals of the production model, which provides a pattern of the deviations from the theoretical ideal. That is the reason why in some cases the actual duration of the PhD could be higher than the standard duration, which could reveal the behavior of the student based on his ability or intentions.

4. WHAT FACTORS INFLUENCE THE DURATION OF THE PHD

4.1. Estimation specification

In the literature analyzing PhD duration, the methodology used is quite different; in this paper, we propose a new approach which we think it could contribute to prove more suitable some questions of the research.

Martín-Román and Moral (2013) applied a SFA to the analysis of the duration of workplace accident leaves to identify the worker behavior distinguished from the psychological or medical reason of the leave. By the same way, we could model the duration of the PhD by a frontier approach. We could think that there is a standard duration for PhD period attributable to the inherent factors of the area of research, the student and their proper thesis and, on the other hand, a duration component attributable to the degree of efficiency of each PhD student, based on some factors such as their own capabilities or the aid to fund this period, which could generate a kind of opportunistic behavior.

The model we estimate comes from equation (3). We suppose that the real duration depends on the standard duration and an additional component which reflects the inefficiency of the student. We could express this idea from the model of Martín-Román y Moral (2013) with the following equation:

$$d_i^R = d_i^S + u_i \tag{4}$$

where d_i^R is the logarithm of the total duration and d_i^S is the logarithm of the standard duration of the PhD. In turn, the standard duration of the PhD could be represented as a function of a vector of inputs used by the student ($\boldsymbol{x}_i$) and technology parameters to be estimated ($\boldsymbol{\beta}$), plus a random error (v_i), independent (uncorrelated) of mean 0 and variance σ_v^2. Because the standard duration is equal to the vector of characteristics and the random error term, we could also express the last equation as:

$$d_i^R = \alpha + \boldsymbol{\beta} \cdot \boldsymbol{x}_i + v_i - u_i \quad (5)$$

The equation (5) can be estimated by maximum likelihood, which seems to be more appropriate. Aigner et al. (1977) proposed a half-normal model under the assumptions $v_i \sim iidN(0, \sigma_v^2)$ and $u_i \sim iidN^+(0, \sigma_u^2)$. This means that $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\lambda^2 = \sigma_u^2/\sigma_v^2 \geq 0$. If *λ=0*, there is no technical inefficiency and all deviations from the frontier are due to noise (Coelli et al., 2005). However, the specification has been extended in the literature to implement other more general distributions of u_i, as the normal truncated model (Stevenson, 1980), a gamma distribution (Green, 1980), which also let the λ varies its form, or the normal half-normal model, which is the one we employed in the estimation.

The parameters λ amd σ^2 are estimated together with the technology parameters in β. Λ can be tested in order to know if the stochastic frontier methodology is necessary (whenever $\lambda = 0$) or technology parameters could be estimated consistently by ordinary least squares (OLS). Battese and Coelli (1995) suggests that the technical inefficiency effect, u_i, in the stochastic frontier model is assumed to be a function of a set of explanatory variables, z_i, a vector of coefficients, δ, plus a random variable, w_i. It could be expressed as following:

$$u_i = z_i \cdot \delta + w_i, \quad (6)$$

The authors pointed out that the explanatory variables in the inefficiency model should include some inputs of the stochastic frontier to provide that the inefficiency is stochastic. Finally, to that aim, it is important to remark that most of the times the location of a variable outside the production function is not clear. That is why econometric results are not always enlightened (Pereira and Moreira, 2007), for example, when a relevant factor is omitted from the production function, it could show that the firm could be more efficient than other one when it is not at all.

4.2 Results

Table 4 presents the results for the estimation of the model with the same comparable explanatory variables for 2006 and 2009. In the first part of the table, we present the results for the estimation of the frontier with three different models (that differ because of the variables considered to the inefficiency), while in the second part of the table, the variables and coefficients of the inefficiency are shown. Appendix A.3 and A.4 contain the results for 2006 model and 2009 model, respectively, following the same structure. The dependent variable used in the estimation is the logarithm of the years of duration of the PhD thesis. (*logDURANO*). The reference take into account to estimate the model is a male, with less than 30 years old on the

moment of the survey, born at Spain, who had received a public administration studentship, working on the area of sciences and with a pure or fundamental PhD research[13].

The coefficients of the production frontier estimated[14] reveal that the duration of the PhD is higher for the women and the people born abroad. It also decreases with the age of the person interviewed, because people older in 2006 and 2009 present a higher duration. Concerning the type of funding received during the PhD, the results show that every other type of funding increases the frontier, especially when we consider other occupation, loans, personal savings and family support and working as researcher or professor or other types of funding. Relating to the research area, PhD associated with medicine, social sciences and humanities significantly increase the frontier with respect to sciences. It is also important to point out that experimental development research reduces the frontier, while applied research increases it.

When we observe the coefficients of the inefficiency variables, it is important to remark that there are considerable differences in the efficiency related to different type of funding and research area of the PhD. Students with a job or who receive loans or familiar savings present higher coefficients than those who have a studentship, as well as students from abroad are less efficient while females are more. However, those students who have an international studentship or a studentship from other Spanish institution or enterprise (not a public administration studentship) are less inefficient. Finally, students from medicine, humanities and quietly social sciences present higher coefficients in terms of duration and, therefore, they are further from the frontier. In the estimation for the year 2009 (Appendix A.4), it is remarkable the significance of having a father working on the university in order to reduce the frontier, and also the inefficiency negative coefficients of some regions, such as Madrid, Cataluña, Comunidad Valenciana and Castilla-La Mancha, which reflects that students born there are more efficient than those from Andalucía.

Finally, we do not appreciate significant differences between 2006 and 2009, except those related to the scope of research and the funding. For example, social sciences and medicine students has increase their inefficiency coefficients in 2009, while the age of the doctor interviewed seems to be more important in 2006 than in 2009.

[13] In 2006 own estimation of the Appendix, a variable identifies if the student would have done the PhD on the same center than the graduate studies (the reference is that he does not). In 2009 own estimation of the Appendix, the reference of the region captured is Andalucía, a public center of education of the PhD student, parents without studies and working on a firm.

[14] The log-likelihood ratio test indicates that the production frontier is better than the cost frontier form with a 1% level of significance.

TABLE 4: Results of the estimation of the comparable frontier for 2006 and 2009

Dependent variable: logDURANO	MODEL 1		MODEL 2		MODEL 3	
VARIABLES	**2006**	**2009**	**2006**	**2009**	**2006**	**2009**
Female	0.0123*	0.0353***	-0.00391	0.0283	-0.00277	0.0292
Born abroad	0.0306	0.0983**	0.0447	0.205***	0.0442	0.199***
AGE						
Between 31 and 40 years	0.164***	0.253***	0.269***	0.162*	0.262***	0.157*
Between 41 and 50 years	0.342***	0.409***	0.570***	0.435***	0.550***	0.413***
Between 51 and 60 years	0.758***	0.807***	1.020***	0.895***	0.986***	0.851***
Between 61 and 70 years	1.011***	1.149***	1.286***	1.211***	1.237***	1.160***
FUNDING						
Other Spanish institution and enterprises studentship	0.123***	-0.0998*	0.0814***	-0.0832*	0.0802***	-0.0784*
International studentship	0.0848	0.0236	0.0567	0.00138	0.0573	-0.000352
Working as researcher or professor assitant	0.214***	0.239***	0.142***	0.161***	0.143***	0.161***
Other occupation	0.480***	0.298***	0.357***	0.222***	0.356***	0.227***
Refund subsidy by employer	0.357***	0.0917	0.252***	0.0581	0.250***	0.0577
Loan, personal savings and familiar support	0.406***	0.265***	0.278***	0.178***	0.274***	0.179***
Other type of funding	0.412***	0.261***	0.302***	0.192***	0.300***	0.191***
RESEARCH AREA						
Engineering	0.0260	0.0172	0.0220	0.00345	0.0160	-0.00729
Medicine	0.111***	0.161***	0.0974***	0.139***	0.0964***	0.134***
Agriculture	0.00211	0.0983*	0.00258	0.0673	-0.00107	0.0632
Social Sciences	0.140***	0.182***	0.114***	0.178***	0.110***	0.171***
Humanities	0.210***	0.278***	0.185***	0.249***	0.184***	0.244***
OTHER VARIABLES						
Years from graduate to PhD studies	-0.0356***	-0.0362***	-0.0356***	-0.0359***	-0.0343***	-0.0325***
Age finishing graduate studies	-0.0358***	-0.0342***	-0.0354***	-0.0335***	-0.0310***	-0.0291***
Applied research	0.0341***	0.00274	0.0339***	0.00632	0.0356***	0.0231
Experimental development	-0.0372***	-0.0295**	-0.0414***	-0.0290**	-0.0426***	-0.0371*
Constant	2.383***	2.273***	2.346***	2.352***	2.247***	2.244***
INEFFICIENCY						
Female			-0.107**	-0.0545	-0.0998*	-0.0418
Born abroad			0.103	0.607**	0.0895	0.565**
Between 31 and 40 years			0.973***	-0.940*	0.925***	-0.956*
Between 41 and 50 years			1.654***	-0.102	1.534***	-0.222
Between 51 and 60 years			1.793***	0.199	1.531***	-0.116
Between 61 and 70 years			1.872***	0.0846	1.468***	-0.366
Other Spanish institution and enterprises studentship	0.927***	-1.073**	0.457***	-0.643**	0.443***	-0.606**
International studentship	0.277	-0.257	0.00182	-0.296	0.00359	-0.291
Working as research and professor assitant	1.143***	0.525	0.479***	0.0901	0.489***	0.0984
Other occupation	1.664***	0.555	0.735***	0.152	0.716***	0.170
Refund subsidy by employer	1.582***	0.320	0.695*	0.0767	0.673	0.0952

	MODEL 1		MODEL 2		MODEL 3	
	2006	**2009**	**2006**	**2006**	**2009**	**2006**
Loan, personal savings and familiar support	1.740***	0.749**	0.822***	0.348	0.796***	0.354
Other type of funding	1.526***	0.418	0.663***	0.0521	0.648***	0.0493
Engineering	0.0439	-0.134	-0.00404	-0.205	-0.0430	-0.285
Medicine	0.775***	1.125***	0.609***	0.864***	0.595***	0.823***
Agriculture	-0.0267	0.644*	-0.0215	0.358	-0.0493	0.336
Social Sciences	0.348***	0.574***	0.169*	0.448***	0.136	0.391**
Humanities	0.477***	0.914***	0.254***	0.612***	0.242**	0.586***
Years from graduate to PhD studies					0.0112*	0.0235**
Age finishing graduate Studies					0.0259***	0.0300**
Applied research					0.0146	0.130
Experimental development					-0.00706	-0.0511
Constant	-3.267***	-2.602***	-3.530***	-1.717***	-4.113***	-2.488***
Observations	**12,625**	**4,121**	**12,625**	**4,121**	**12,625**	**4,121**

Source: own estimation based on HRST survey
Note: (*) indicates significance level of 10%, (**) of 5%, and (***) of 1%.

5. CONCLUSIONS

This paper attempts to measure the differences in the duration of the PhD studies at Spain. Studying the time-to-completion we could obtain a measure of the efficiency of some students instead of other, and this is an important way to know it there are some factors which affect this efficiency. Using an stochastic frontier perspective, we could find the most effective duration of the PhD studies associated with some characteristics, and this let us to know what students are less effective than others.

The results of the estimation of the model suggest that those students researching on humanities, social sciences and medicine are more inefficient than those from sciences and engineering, but also it is confirm the previous evidence for other countries than public studentships are associated with more efficient students, while those students who work as researcher or professor during the PhD are less efficient.

To conclude, public funding affects significantly the time-to-completion. However, we have mentioned before that fellowship students could also be better than other students enrolled in a PhD program. It also depends on the intention that the student had when he begun the PhD: some students prefer to begin an academic or research career while others prefer to work on the private sector and combine it as postgraduate studies or begin a PhD once they have already

begun in the labor market. Because of that, it could be interesting to analyze if there is a kind of dead-weight effects on the duration of the PhD along the students who have some type of public funding (they could finished their thesis more rapidly than the benefit period of the fellowship) or if the duration of the PhD has some effect on their career prospects at Spain. But these ideas should need another paper.

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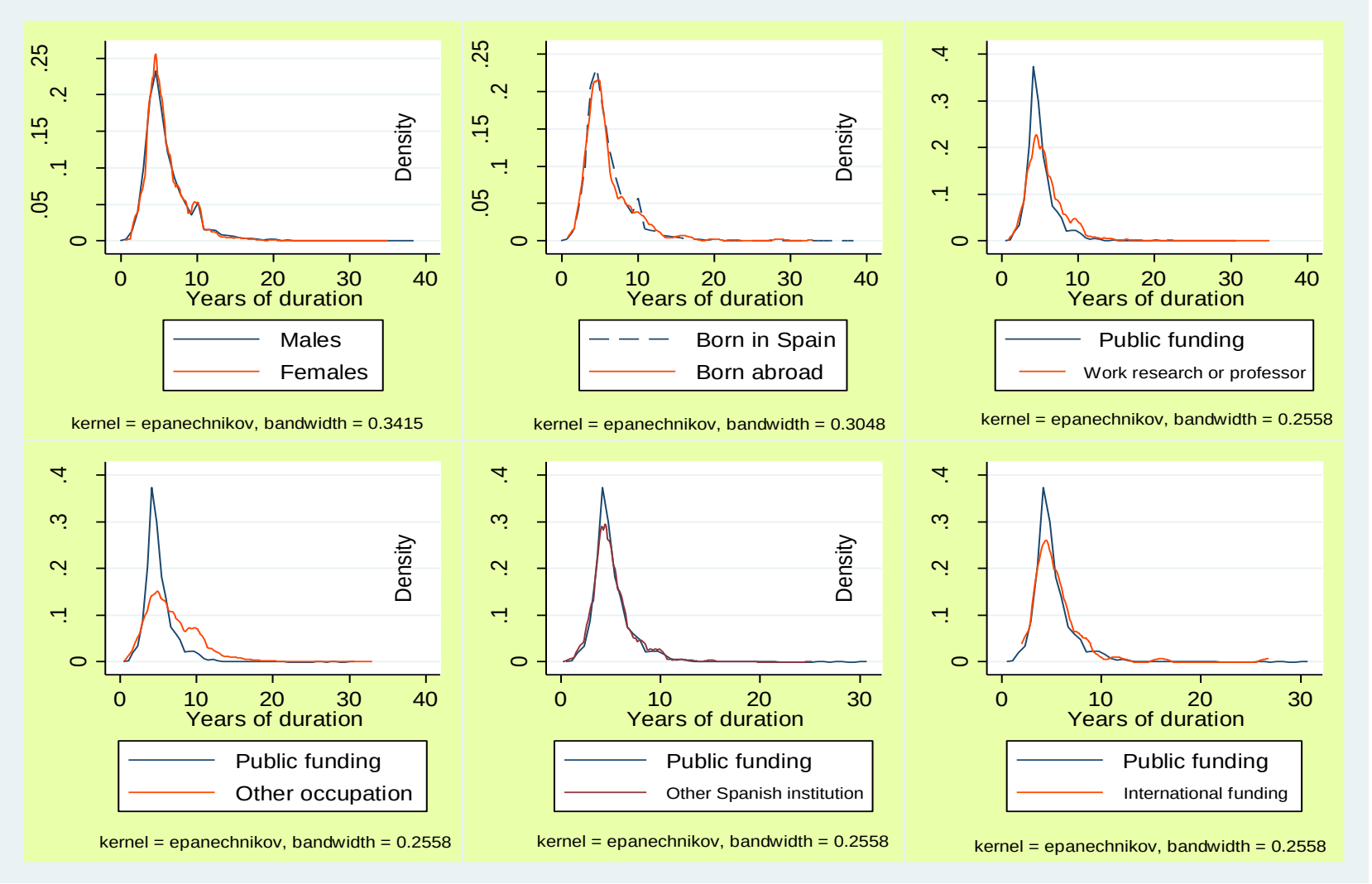
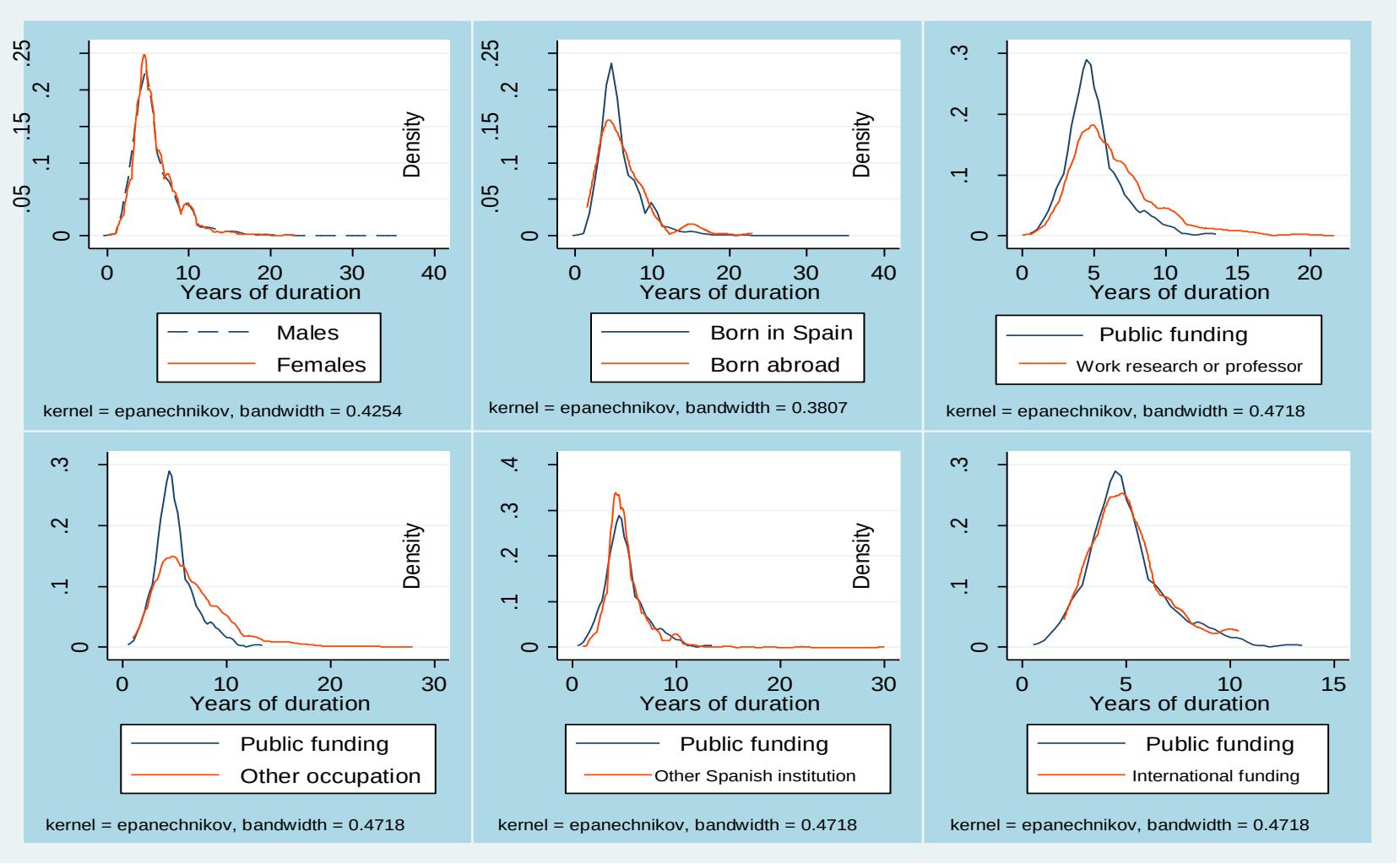
Appendix A.1: Distribution of the PhD duration by characteristics in 2006



Appendix A.2: Distribution of the PhD duration by characteristics in 2009



Appendix A.3: Stochastic frontier estimation in 2006

Variables	MODEL 1	MODEL 2	MODEL 3
Female	0.0173**	0.00218	0.00323
Born abroad	0.0299	0.0415	0.0409
Between 31 and 40 years	0.163***	0.268***	0.261***
Between 41 and 50 years	0.338***	0.566***	0.544***
Between 51 and 60 years	0.749***	1.009***	0.972***
Between 61 and 70 years	1.005***	1.275***	1.223***
Public administration studentship (not university)	-0.0834***	-0.0531***	-0.0524***
Enterprise studentship	0.145***	0.113**	0.109**
Other institution studensthip	0.0593	0.0361	0.0351
International studentship	0.000752	0.00243	0.00409
Research assistant	0.115**	0.0576	0.0590
Professor assistant	0.130***	0.0951***	0.0974***
Other full-time occupation	0.426***	0.334***	0.334***
Other part-time occupation	0.240***	0.175***	0.175***
Refund subsidy by employer	0.273***	0.200**	0.199**
Loan	0.164	0.124	0.113
Personal savings	0.400***	0.295***	0.291***
Familiar support	0.182***	0.126***	0.127***
Other type of funding	0.330***	0.254***	0.251***
Engineering	0.0267	0.0217	0.0161
Medicine	0.102***	0.0889***	0.0879***
Agriculture	0.00399	0.00665	0.00338
Social Sciences	0.145***	0.118***	0.113***
Humanities	0.221***	0.195***	0.193***
Same university	-0.0363***	-0.0342***	-0.0357***
Years from graduate to PhD studies	-0.0371***	-0.0373***	-0.0359***
Age finishing graduate studies	-0.0365***	-0.0363***	-0.0318***
Applied research	0.0323***	0.0322***	0.0329***
Experimental development	-0.0341***	-0.0382***	-0.0392***
Constant	2.507***	2.439***	2.338***
INEFFICIENCY			
Female		-0.102*	-0.0952*
Born abroad		0.0815	0.0663
Between 31 and 40 years		1.015***	0.956***
Between 41 and 50 years		1.703***	1.568***
Between 51 and 60 years		1.833***	1.549***
Between 61 and 70 years		1.894***	1.460***
Public administration studentship (not university)	-0.494**	-0.168	-0.158
Enterprise studentship	1.344***	1.015***	0.984***
Other institution studensthip	0.710***	0.451**	0.444**
International studentship	-0.180	-0.146	-0.134
Research assistant	0.900***	0.495**	0.507**
Professor assistant	0.538***	0.251	0.272*
Other full-time occupation	1.184***	0.584***	0.573***
Other part-time occupation	0.830***	0.394**	0.383**
Refund subsidy by employer	1.069**	0.527	0.511

Loan	1.198*	0.845	0.801
Personal savings	1.272***	0.621***	0.590***
Familiar support	1.024***	0.648***	0.658***
Other type of funding	1.000***	0.485***	0.478***
Engineering	0.0953	0.0391	0.00331
Medicine	0.783***	0.616***	0.603***
Agriculture	0.0102	0.0190	-0.00695
Social Sciences	0.415***	0.225**	0.191**
Humanities	0.551***	0.312***	0.300***
Same university			-0.0115
Years from graduate to PhD studies			0.0123*
Age finishing graduate studies			0.0271***
Applied research			0.00806
Experimental development			-0.00607
Constant	-2.784***	-3.443***	-4.044***
Observations	12,625	12,625	12,625

Appendix A.4: Stochastic frontier estimation in 2009

Variables	MODEL 1	MODEL 2	MODEL 3
Female	0.0362***	0.0369**	0.0369**
Between 31 and 40 years	0.240***	0.171*	0.167*
Between 41 and 50 years	0.380***	0.411***	0.386***
Between 51 and 60 years	0.782***	0.861***	0.798***
Between 61 and 70 years	1.129***	1.201***	1.127***
Other Spanish institution studentship	0.0557	0.0618	0.0564
International public studentship	0.139	0.101	0.0494
Other international institution studentship	0.0914	0.0448	0.00732
Research or professor assistant	0.348***	0.255***	0.239***
Other occupation	0.405***	0.322***	0.316***
Refund subsidy by employer	0.201*	0.133	0.118
Loan, personal savings and familiar support	0.376***	0.281***	0.273***
Other form	0.344***	0.269***	0.253***
Engineering	0.0166	0.00141	-0.0196
Medicine	0.166***	0.149***	0.130***
Agriculture	0.134**	0.104*	0.0928*
Social Sciences	0.175***	0.169***	0.158***
Humanities	0.259***	0.244***	0.229***
Years from graduate to PhD studies	-0.0376***	-0.0366***	-0.0321***
Age finishing graduate studies	-0.0343***	-0.0339***	-0.0286***
Applied research	0.00416	0.00519	0.0236
Experimental development	-0.0347***	-0.0337**	-0.0518**
Aragón	-0.0361	-0.0773	-0.0757
Asturias	-0.0502	-0.0880*	-0.0882*
Baleares	-0.0162	-0.0113	-0.0181
Canarias	0.0299	-0.0544	-0.0522
Cantabria	-0.0765*	-0.0349	-0.0216
Castilla y León	-0.00465	-0.0125	-0.0158

Castilla - La Mancha	0.0104	-0.0763	-0.0774
Cataluña	0.0470*	-0.0187	-0.0233
Comunidad Valenciana	0.0325	-0.0252	-0.0320
Extremadura	0.0179	-0.00502	-0.00959
Galicia	0.0286	0.00108	-0.00372
Madrid	0.00270	-0.0341	-0.0422
Murcia	-0.0225	0.0270	0.0346
Navarra	-0.0322	-0.0396	-0.0331
País Vasco	0.0553*	0.0411	0.0306
Rioja	0.0928**	0.115*	0.121*
Ceuta y Melilla	0.105	-0.00794	0.00684
Primary private-subsidiased school	-0.0670***	-0.0614**	-0.0969**
Primary private school	-0.0301	-0.0238	-0.00301
High private-subsidiased school	0.0755**	0.0718**	0.130***
High private school	0.107***	0.0969***	0.0606
Private-subsidiased college	-0.0474	-0.0417	-0.0547
Private college	-0.0886***	-0.0794**	-0.0165
Same type of school	-0.0641**	-0.0562**	-0.0484
Mother not-finish primary studies	-0.00492	0.00361	0.00596
Mother primary or secondary studies	-0.0504*	-0.0434	-0.0420
Mother technical education I	-0.0212	-0.0156	-0.0127
Mother technical education II	-0.112*	-0.0995*	-0.0973
Mother high or college school	-0.0311	-0.0278	-0.0245
Mother technical graduate studies	-0.0484	-0.0366	-0.0353
Mother higher graduate studies	-0.0769*	-0.0611	-0.0568
Mother postgraduate studies	-0.0979	-0.0924	-0.0868
Mother, not answer	-0.179*	-0.180*	-0.176
Father not-finish primary studies	-0.0180	-0.0230	-0.0241
Father primary or secondary studies	0.0142	0.00906	0.00690
Father technical education I	0.0294	0.0200	0.0151
Father technical education II	-0.0101	-0.0168	-0.0184
Father high or college school	0.0103	0.00775	0.00864
Father technical graduate studies	-0.00805	-0.0136	-0.0145
Father higher graduate studies	0.00751	0.00636	0.00661
Father postgraduate studies	-0.00691	-0.00945	-0.0102
Father, not answer	0.109	0.121	0.122
Father working public administration	-0.0125	-0.0141	-0.0132
Father working university	-0.0778**	-0.0809**	-0.0780**
Father working other institution	-0.131	-0.136	-0.144*
Father has never worked	-0.435	-0.433	-0.435
Mother working public administration	0.0197	0.0151	0.0129
Mother working university	0.0259	0.0341	0.0325
Mother working other institution	0.114	0.109	0.117*
Mother has never worked	-0.0102	-0.0120	-0.0139
Mother others	0.318	0.327	0.336
Constant	2.268***	2.367***	2.243***
INEFFICIENCY			
Female		0.00134	0.00930

Between 31 and 40 years		-0.740	-0.741
Between 41 and 50 years		-0.00433	-0.142
Between 51 and 60 years		0.265	-0.157
Between 61 and 70 years		0.255	-0.356
Other Spanish institution studentship	0.672	0.520*	0.483
International public studentship	0.920	0.477	0.0855
Other international institution studentship	0.775	0.177	-0.158
Research or professor assistant	1.649***	0.791***	0.686***
Other occupation	1.694***	0.902***	0.826***
Refund subsidy by employer	1.573**	0.894	0.806
Loan, personal savings and familiar support	1.915***	1.115***	1.042***
Other form	1.379***	0.634**	0.524*
Engineering	-0.103	-0.215	-0.377
Medicine	1.159***	0.931***	0.795***
Agriculture	0.804**	0.495	0.394
Social Sciences	0.584***	0.457***	0.359**
Humanities	0.796***	0.599***	0.522***
Years from graduate to PhD studies			0.0303**
Age finishing graduate studies			0.0351**
Applied research			0.150
Experimental development			-0.136
Aragón		-0.371	-0.381
Asturias		-0.348	-0.344
Balears		-0.0201	-0.0359
Canarias		-0.634*	-0.629*
Cantabria		0.237	0.308
Castilla y León		-0.0867	-0.116
Castilla - La Mancha		-0.724*	-0.742*
Cataluña		-0.544**	-0.567**
Comunidad Valenciana		-0.455*	-0.511**
Extremadura		-0.204	-0.213
Galicia		-0.197	-0.245
Madrid		-0.276	-0.347*
Murcia		0.239	0.296
Navarra		-0.130	-0.0702
País Vasco		-0.0377	-0.138
Rioja		0.155	0.190
Ceuta y Melilla		-0.657	-0.509
Primary private-subsidiased school			-0.281
Primary private school			0.167
High private-subsidiased school			0.471*
High private school			-0.271
Private-subsidiased college			-0.0796
Private college			0.503*
Same type of school			0.110
Constant	-3.751***	-2.392***	-3.313***
Observations	3,967	3,967	3,967