Money for nothing?*

The net costs of medical training

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October 24, 2009

Abstract

One of the stages of medical training is the residency programme. Hosting institutions often claim compensation for the training provided. How much should this compensation be?

According to our results, given the benefits arising from having residents among the house staff, no transfer (either tuition fee or subsidy) should be set to compensate the hosting institution for providing medical training. This paper quantifies the net costs of medical training, defined as the training costs over and above the wage paid.

We jointly consider two effects. On the one hand, residents take extra time and resources from both the hosting institution and the supervisor. On the other hand, residents can be regarded as a less expensive substitute to nurses and/or graduate physicians, in the production of health care, both in primary care centres and hospitals. The net effect can be either positive or negative. We use the fact that residents, in Portugal, are centrally allocated to National Health Service hospitals to treat them as a fixed exogenous production factor. The data used comes from Portuguese hospitals and primary care centres.

Even though teaching institutions have a higher cost level (around 2%), cost function estimates point to a small negative marginal impact of the residents in the total cost structure of hospitals (-0.04%) and primary care centres (-0.9%). Nonetheless, there is a positive relation between size and cost to the very large hospitals and primary care centres. Overall, the net costs of medical training appear to be quite small.

Keywords: costs; medical training.
JEL: I12, I18.

*This paper is based on a working paper, "The net costs of medical training" (joint work with Ana Simões), available at SSRN: http://ssrn.com/abstract=1119822. We have benefited from useful comments and suggestions of Andrew Street, Miguel Gouveia, Carlota Quintal, three referees and several seminar participants. The usual disclaimer applies.

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1 Introduction

Graduate Medical Education (GME) is the last stage of medical training, following the undergraduate studies. GME is a two-stage residency program. On the first stage, the resident completes a transitional year (or couple of years),[1] carrying out one to three months shifts in several clinical specialties. Candidates are given daily experience of the different specialties, helping them in the ongoing career choice. On the second stage, the resident is assigned to a specialty programme and advisor, according to some matching process, and specializes in a specific medical area. The teaching institution hosting the programme bears the responsibility for the resident's training.

The problem we address in this paper is whether the extra output from having residents amongst the working staff compensates for the effort of training them. If this is not the case, a monetary transfer should be set, in order to ensure enough GME positions. The cash transfer could be guaranteed by either the sponsor of the Residency programme or the trainee doctor (resident).[2] In sum, should there be a cash transfer to the hosting institution?

To answer this question, we look at the impact of having a specific exogenous resource, residents,[3] on the institutions' cost structure. These cost functions have been estimated in the literature following two different approaches: behavioral cost functions and cost minimizing functions.

Behavioral cost functions have typically been used to explain variations in cost per unit of output among hospitals. The other branch of the literature, cost minimizing studies, has focused on the minimum cost of providing a given volume of output as a functions of an exogenous vector of input prices and the volume of output. The paper by Bilodeau, Cremieux, and Ouellette (2000) provides evidence that even when the health system relies merely upon public hospitals, these behave as cost-minimizing firms, at least in the short run. Including physicians (in our case, residents) as a quasi-fixed input is seen as crucial to avoid bias resulting from omitted variables.

[1] The terms resident, intern and trainee doctor will be used interchangeably. It stands for a student which has graduated from Medical School and has engaged a Graduate Medical Education - specialty or general practice - process.

[2] In Europe this would be the Ministry of Health, in most countries.

[3] The importance of the exogeneity assumption will be explained later on.

We estimate the hosting institutions' cost minimizing function making use of the particular institutional setting to allocate residents to hospitals (detailed below). If the net cost of medical training (defined as the cost effect above wage) turns out to be negligible, there should be no cash transfer at all. On the contrary, if training residents is an extra cost to the institution, the estimates of the cost function provide a way to quantify the value of the requested transfer.

The direct impact of residents on costs is the wage paid by the hosting institution. However, there are other cost effects; the first ones arise from the twofold relationship between the various types of labor required to provide medical care. The most obvious is the relation between the supervisor and resident's work. A physician spends part of his working hours training and supervising the health care provided by residents. Nonetheless, he increases the time available to treat patients by assigning other tasks (night shifts, paper work, research assistance) to the trainee doctor. Savings can also arise from the relation between residents' and nurses' labor. A resident is available to perform a number of routine procedures (sutures, blood tests, etc.), usually carried out by nurses and/or other technicians.

Having residents performing these tasks doesn't go without cost. In fact, they spend, on average, more time and resources (mostly diagnosis procedures and tests) with each patient. Estimates indicate an excess amount of 9 to 30% of costs of teaching hospitals, adjusting for differences in the case mix (Rich et al., 1990). Residents are pointed as the main factor behind the increased level of resource utilization causing the increase in teaching care costs (Rich et al., 1990; and Kane et al., 2005).

The effect of teaching residents is measured by their contribution to the output of the institution, in terms of discharges and outpatient visits. It is not possible to measure the output "training-a-resident" *per se*, even though it is in fact an output of the time spent by senior physicians delivering health care.

Therefore, the wage paid is only a fraction of the cost of training residents. If residents are to be considered, the hosting institution changes the choice of the type of resources and their allocation in the provision of health care, and as a result the optimal production structure differs between teaching and non-teaching hospitals.

We use data from Portugal, applying a model that is common to standard graduate medical education programmes. Two particular features of the Portuguese system allow us to isolate the cost effect of residents. The first one is the exogeneity of the process by which residents are assigned to hosting institutions. The second is the fact that GME is provided almost free of charge to students, even though they represent a cost to the provider of care. Should this cost lead to a monetary transfer to the hosting institution, beyond wage? Or is it the case that residents, a less expensive resource, are a valuable asset, that leads to efficiency gains? Given the structural differences in the provision of acute (specialty training) and primary health care (general practitioner training, in the Portuguese healthcare system), both cases are treated separately.

Our results indicate that both the hospitals' and primary centres cost structures are affected by the presence of residents. The average net cost of medical training on hospitals is negative (around 24,000€) and the same happens at Primary Care Centres. Therefore, the net cost of medical training turns out to be a net benefit. Replication of the approach to other countries and data sets will provide further knowledge of medical training costs.

The paper is organized as follows: Section 2 provides a brief description of the existing literature on Medical training and related cost efficiency analysis; Section 3, Graduate Medical Education in Portugal, contains the features of Graduate Medical Education in general, and some important characteristics of the Portuguese programme; the model is presented in Section 4, followed by the data (Section 5) and estimation results (Section 6 and 7) in both acute and primary care settings. Section 8 shows the net cost effects of training. Section 9 briefly reports on an informal survey on residents' workload, and Section 10 concludes.

2 Literature review

The analysis of medical training has focused on both funding and efficiency issues. One of the main topics on Graduate Medical Education is the identification of direct and indirect costs of medical training, since direct costs of education (wages and teaching hours) are easy to measure, but indirect costs are for the most part unobservable.

The Indirect Medical Education costs (IME) have been studied by several authors. The study by Anderson et al. (2001) provides an overview of the policy debate around GME. The analysis by Thorpe (1988), Rogowski and Newhouse (1992) and Dalton and Norton (2001) studies the Medicare GME reimbursement formulae. Regression analysis was used to estimate the indirect costs, to find whether the reimbursement formulae is the most suitable and if it provides the proper incentives to hosting institutions. The effect of teaching on costs might arise from the higher level of diagnostic and therapeutic services, extra time to perform routine tasks and the faculty supervision required by residents, as argued by Blumentahl et al. (1997). The indirect benefits are not so straightforward to measure. Nonetheless, some of these authors state that indirect medical education costs seem to be redundant - hospitals are reimbursed for training costs once by residents and a second time by the government. Overall, no clear picture about GME emerges and, as Newhouse and Wilensky (2001) explain, the debate goes on.

The other line of research on GME focuses on the link between teaching status and efficiency.[4] The paper by Jensen and Morrisey (1986) identifies differences between the production of teaching and non-teaching hospitals due to the role of residents in the production of health care. Furthermore, there is evidence of a higher cost level for teaching hospitals (Sloan et al., 1993, and Farsi and Filippini, 2008). For the last twenty years many authors tried to understand the (in)efficiency issues behind those cost differences.

The tools most widely applied to cost efficiency analysis are stochastic frontier (SFA) and data envelopment analysis (DEA).[5] A review of the studies conducted using stochastic frontier analysis is available in Rosko (2004). The authors aim to measure the inefficiency of US teaching hospitals; Linna and Häkinnen (2006) do the same for Finnish hospitals. The paper by Grosskoptf et al. (2001) applies DEA to a sample of 213 US teaching hospitals.[6] The authors conclude that teaching hospitals could reduce substantially the level of inputs keeping the output level, but are unable to do so due to inefficiency in the production of health care. The choice of the most suitable estimation technique depends upon the type of data available (Jacobs, 2001).

[4]By teaching hospital/primary care centre we mean an institution which has at least one resident enrolled in either the first stage (foundation years, in the UK) or a specialty/GP training programme.

[5]See Jacobs, Smith and Street (2006) for a discussion on the topic and examples.

[6]These techniques will be explained later on, when we address the methodology used.

3 Graduate Medical Education in Portugal

Medical education has two stages. In the first stage, the undergraduate years, students acquire a strong theoretical background. The purpose of the second stage, graduate medical education, is to empower residents with skills that allow them to become (independent, i.e., responsible for their actions) practitioners of a specific medical specialty. Each health system has its own GME plan, but some of the features are common to all of them.

When a resident is in the first phase of GME, any decision concerning the patient's medical condition and treatment is subject to the approval of the supervising physician, who bears the responsibility for the treatment. In the United Kingdom (UK), this stage corresponds to the first year of the Foundation Programme; in Portugal, to the Common Year Internship.

The final stage of GME lasts from three to six years, depending on the specialty. The admission process to specialty programmes (specialty or primary care practice training) relies on the matching between residents and the residency positions issued by teaching hospitals or medical centres.[7] In some countries, such as the US or the UK, candidates apply to residency programmes offered by teaching hospitals, and bargain over wage and labour conditions. We expect the wage to account for the productivity of the resident, presumably lower than the one attained by a senior physician. There are matching processes aiming to optimize the allocation of residents to the vacancies issued by teaching hospitals.[8]

However, in other countries, teaching institutions do not bargain over candidates and the wage to be paid. Instead, the National Accreditation Council sets the number of vacancies and residency programmes available at each teaching institution. The process of matching residents with positions is based solely on the candidate's profile resulting from National Classifying Examinations and undergraduate student records, thus being exogenous to teaching institutions.

[7] In order to become a teaching hospital or medical centre, the institution is subject to an accreditation process, having to fulfill a set of prerequisites regarding facilities, services and availability of supervising physicians. In Portugal, the process is coordinated by the National Council of the Resident (CNMI). In the US, the process is lead by the Accreditation Council for Graduate Medical Education (ACGME). The same type of advisory board exists in many other countries.

[8] In the US, the matching process is run by the National Resident Match Program for the majority of GME programmes.

The exogeneity of the matching process to the hosting institution is the key assumption for understanding the cost effect of residents on the production of health care. If teaching institutions cannot choose the residents, wages and the number and type of positions available, each resident becomes a fixed factor in the production of health care. We can measure their impact on the cost structure of the hosting institution using regression analysis.

The Portuguese GME process is an example of such a system. Medical training programmes are highly regulated by the Ministry of Health (MoH).[9] The demand for residents' labor, i.e., the list of available positions in training programmes, is published by the National Council for Medical Residencies (NCMR), with the advice of the National Council of Physicians, and issued by the MoH. Each institution's ability to host residents (how many and for which specialties) is evaluated by the NCMR, and there's nothing the hospital or primary care centre can do about it. Moreover, the wage is fixed by the MoH.

The supply of residents' labour is also regulated. In Portugal, as well as in France, in order to access the last stage of medical training, residents sit the National Classifying Examinations (NCE). Given NCE grades and the undergraduate student record, the MoH ranks the students. When the matching process is over, teaching institutions are informed about the residents they are to train over the next few years.

Such a system allows to isolate the cost effect of residents. We have a "laboratory" to analyze the impact of having a fixed and exogenous number of residents, and check whether there is a related increase in costs, beyond the wage cost. The crucial feature is the exogeneity of the matching process. One may have the concern that politics and reputation effects will permeate the process, with some hospitals more likely than others to get their requests satisfied. We should be worried if there was a selection effect related to costs. However, the fact that vacancies open by the Ministry of Health must respect accreditation for training at the medical service level by the Portuguese Medical Association (independent of Government) and it is subject to public scrutiny suggests these effects play a minor and non-systematic role.

[9] See Barros et al. (2007) for a review of the Portuguese Health System, particularly the organizational structure of the Ministry of Health and related councils responsible for GME.

4 The empirical framework

We estimate the effect of residents on an institution's total cost. The estimation procedure is defined taking into account the particularities of the production factors involved in medical care. Along with the demand for physical capital inputs (facilities, beds, laboratories, medical devices, taken as a "composite bundle"), the provision of health care requires highly specialized labor input, both medical ($\mathbf{L_m}$) and nursing ($\mathbf{L_n}$). Assume there are three labor inputs able to perform these tasks - physicians (L_1), residents (L_2) and nurses (L_3). The interaction among these can be written as:

$$\mathbf{L_m} = L_1 + \beta L_2 \tag{1}$$

$$\mathbf{L_n} = L_3 + \theta L_2. \tag{2}$$

The demand for medical labor can be met by both senior physicians and residents. We cannot assume that the medical care provided by each of the types of labor is equivalent. If it was, the parameter β would be equal to one. If residents are able to perform some of the tasks carried out by physicians (or the same but at a different pace)[10], the parameter is such that $\beta \in (0, 1)$. In any case, the rate at which one type of labor input substitutes for the other is assumed to be constant. Residents increase the demand for physicians if not only they cannot replace doctors when providing medical care but also prevent them from doing so ($\beta < 0$). The same logic applies to nurse work and the parameter θ. We could also think about different forms of substitutability, but the main message would go through.[11]

The goal of an institution hosting residents is to find the best way to allocate available resources, in order to produce the maximum output (medical care) at the lowest cost. We focus on cost function analysis. The data available (input prices, output quantities and total expenditure on the inputs used) is suitable to

[10] According to Folland, Goodman and Stano (2006, pp. 344-349), there is evidence that residents increase medical care production in terms of discharges, even though their contribution is below one could expect, given the higher rate of resource utilization.

[11] By writing the interaction equations as

$$\mathbf{L_m} = L_1 + \beta f(L_2)$$
$$\mathbf{L_n} = L_3 + \theta g(L_2),$$

we can assume different forms for the substitutability pattern. For example, decreasing returns to scale is given by $g(L_2) = \sqrt{L_2}$.

estimate the cost function (using several econometric techniques)[12] and to check for the robustness of the results.

Formally, the institution faces the following optimization problem:

$$\min_{L_1,L_3,K} \quad C = \sum_{i=1}^{3} w_i L_i + rK \tag{3}$$
$$s.t. \quad G(q_1, q_2, q_3) = F(L_1 + \beta L_2, L_3 + \theta L_2, K). \tag{4}$$

where C stands for total cost of production, G is total output, F is the technological relationship using inputs in the transformation function, L_1 denotes senior physicians, L_2 denotes residents, L_3 stands for nurse staff, K represents other inputs. Finally, w_j denotes average wage for the jth type of labour input and r is the cost of capital.

One important feature of our model is the exogeneity of L_2. The number of residents is a fixed factor for each institution, with a strictly exogenous price. Both the number of residents and the wage paid are set by the MoH, as described in the previous section. In face of that, the institution cannot treat residents as a variable factor, similar to physicians and nurses. Still, it can adjust the use of variable inputs to the existence of a higher (or lower) number of residents.

Therefore, the optimization problem can be written as

$$\min_{L_1,L_3,K} L = \sum_{j=1}^{3} w_j L_j + rK + \lambda \left(G(q_1, q_2, q_3) - F(L_1 + \beta L_2, L_3 + \theta L_2, K) \right), \tag{5}$$

incorporating the constraint. By direct application of the envelope theorem in the optimal solution, the impact of increasing the number of residents is given by

$$\frac{\partial L}{\partial L_2} = w_2 - \beta w_1 - \theta w_3 = \omega \tag{6}$$

whichever the functional form of $G(\cdot)$ and $F(\cdot)$.

We can follow two approaches to capture the effect described in equation (6). The first one is to estimate a standard Cobb-Douglas cost function, given by

$$C_i = \omega L_{2i} + \Gamma X_i + \varepsilon_i, \tag{7}$$

[12] Along with heteroskedasticity consistent OLS and the robust regression, we were able to estimate a stochastic cost frontier. The advantage of doing so is the possibility of accounting for multiple outputs, quasi-fixed inputs and exogenous input prices, which are important features of our model (see Kumbhakar and Lovell (2000, pp. 131-136)).

where ω is the coefficient of interest. Its sign, significance and magnitude determine the relevance of bearing the fixed cost of training a resident for the institution's cost structure. The focus is on the average value of the impact. The outputs and control factors are captured in the X_i matrix, and ε_i is the disturbance term.

The second approach is to estimate directly the substitutability parameters β and θ. Combining equations (6) and (7), we can estimate the cost net of residents function ($\widetilde{C}_i$) using

$$\widetilde{C}_i = C_i - w_2 L_{2i} = -\beta\left(w_{1i} L_{2i}\right) - \theta\left(w_{3i} L_{2i}\right) + \Gamma X_i + \delta_i. \tag{8}$$

The parameter estimates resulting from this equation can be used to compute the impact ω in equation (6), together with average wages.[13] However, the direct estimation of the parameters imposes much more structure on the estimates than the previous approach. For the time being we have sidestepped the estimation of the substitutability parameters, given the inconclusive results arising from the fact that the parameters have to be taken as equal across all hosting institutions.[14]

5 Data and Methodology

5.1 Data

The dataset combines information provided by the Ministry of Health (MoH) and other public institutions. The information gives rise to two separate datasets, one with the data collected from hospitals (2002 to 2004)[15], in charge of all the specialty training programmes, and a single cross-section from Primary Care Centres (2005), where family or general practitioners are trained. Information was provided by the MoH and other public institutions yielding two separate datasets, one for each type of medical training (specialty (hospitals) and GP(primary care centres)). Tables 1 and 2 summarize the main variables included in the analysis of hospitals' costs.[16]

[13] The value of w_2 is not as straightforward as one could expect, since it has to take into account the increase in wages along residency years. The analysis will consider the total number of residents, treating them as equal. The average wage is a weighted average, combining two years of internship and four years of specialty residency. Social contribution amounts to 23,75% of the wage, leading to wage cost of $25539,36$€per resident, per year.

[14] Details available from the authors upon request. See also the previous working paper version.

[15] We take the observations as pooled cross section, without taking into account the possible panel structure of the data. This option is plausible given the changes in management rules, mergers between hospital's administrative boards and missing observations that occurred in the period. Panel data estimation procedures didn't add much information to the results.

[16] See Appendix for a full description of the variables' sources.

Tables 3 and 4 do the same for primary care centres data.

Variables in Table 1 have their usual meaning.[17] Variables in Table 2 explore and account for specific features of the Portuguese data. A major change in management rules applicable to public, NHS, hospitals has occurred in 2003 for roughly half of the hospitals and has been extended to further, but not all, hospitals in subsequent years. Dummy variable D SA accounts for the role of this change. [18] Portugal is divided into five health regions (plus two autonomous regions, Azores and Madeira, not included in the analysis). Potential regional differences are captured by regional fixed effects. Portuguese hospitals are divided into three categories according to the hospital's type. Central hospitals (Level 3) are large units with high intensity of technology. District hospitals (Level 2) are medium sized, and District - Level 1 are small units, with low differentiation. Dummy variables Level 1 to 3 capture the effect of the type of hospital on the cost structure. The case mix index is a weighted average if DRG (diagnosis related group) cases. The weight associated to each DRG episode was administratively determined.

[17]We interchangeably use the terms resident, intern, trainee resident to describe a medical student, enrolled in some Graduate Medical Education Programme. The term physician refers to a senior or graduated physician who has already finished medical studies, including graduate medical education. Even if an institution doesn't host any residency programmes, it will have physicians delivering medical care, hence positive house staff expenditures.

[18]For further discussion of this change, see Barros and Simões (2007).

Table 1: Variable definitions, means and standard errors - hospitals

Definition	Sample statistics					
	All hospitals			Teaching hospitals		
	Mean	Min	Max	Mean	Min	Max
Physicians (number)	200 (239.54)	7	1112	253 (253.53)	7	1112
Residents (number)	43 (79.14)	0	557	57 (87.00)	1	557
Nurses (number)	350 (329.40)	34	1598	427 (339.14)	49	1598
Total cost (in M€)	5.31M€ (5.82M€)	4.15M€	29.0M€	6.65M€ (6.11M€)	4.44M€	29.0M€
House staff expenditure (in M€)	2.87M€ (2.89M€)	0.67M€	14.3M€	3.56M€ (2.98M€)	2.84M€	14.3M€
Outpatient visits (number)	96095 (92954)	5259	467734	119909 (94959)	11616	467734
Discharges (number)	11270 (9266.77)	441	47851	13764 (9015.41)	441	47851
Emergency **R**oom episodes (number)	84211 (52759.31)	0	249420	94171 (55602.5)	0	249420
Case-mix index	1.07 (0.352)	0.467	2.72	1.08 (0.387)	.467	2.72
Beds (number)	307 (267.20)	10	1491	373 (269.78)	10	1491
		N=202			N=151	

The standard error is reported in parentheses below the mean.

Table 2: Variable definitions, means and standard errors - hospitals (contd.)

Code	Definition	Sample statistics All hospitals	Sample statistics TH
D SA	==0 if management rules didn't change	0.233	0.291
		(0.424)	(0.456)
MedSchool	==1 if Medical School	0.213	0.285
		(0.410)	(0.453)
D 2002	==1 if year 2002	0.342	0.344
		(0.475)	(0.477)
D 2003	==1 if year 2003	0.332	0.331
		(0.472)	(0.472)
D 2004	==1 if year 2004	0.327	0.325
		(0.470)	(0.470)
RHA Alentejo	==1 if Regional Health Administration Alentejo	0.045	0.060
		(0.207)	(0.238)
RHA Algarve	==1 if Regional Health Administration Algarve	0.030	0.020
		(0.170)	(0.140)
RHA Centro	==1 if Regional Health Administration Centro	0.351	0.278
		(0.479)	(0.450)
RHA LVT	==1 if Regional Health Administration LVT	0.297	0.351
		(0.458)	(0.479)
RHA Norte	==1 if Regional Health Administration Norte	0.277	0.291
		(0.449)	(0.456)
Level 3	==1 if Central Hospital	0.233	0.305
		(0.424)	(0.462)
Level 2	==1 if District Hospital	0.584	0.623
		(0.494)	(0.486)
Level 1	==1 if District - level 1 Hospital	0.183	0.073
		(0.388)	(0.261)
D 1Q TH beds	==1 if teaching hospital (TH) and belongs to 1^{st} quartile of beds	0.059	0.079
		(0.237)	(0.271)
D 2Q TH beds	==1 if TH and belongs to 2^{nd} quartile of beds	0.213	0.285
		(0.410)	(0.453)
D 3Q TH beds	==1 if TH and belongs to 3^{rd} quartile of beds	0.233	0.311
		(0.424)	(0.465)
D 4Q TH beds	==1 if TH and belongs to 4^{th} quartile of beds	0.243	0.325
		(0.430)	(0.470)
R 1Q beds	Residents * belongs to 1^{st} quartile of beds	0.416	0.556
		(2.091)	(2.405)
R 2Q beds	Residents * belongs to 2^{nd} quartile of beds	2.970	3.974
		(7.438)	(8.374)
R 3Q beds	Residents * belongs to 3^{rd} quartile of beds	6.960	9.311
		(16.911)	(19.004)
R 4Q beds	Residents * belongs to 4^{th} quartile of beds	32.193	43.066
		(81.463)	(91.767)
Physicians*nurses	Nurses * number of graduated physicians	145198	190073
		(333019)	(374292)
Physicians*residents	Residents * number of graduated physicians	26173	35014
		(80841)	(91900)
Residents*nurses	Residents * number of nurses	37490	50153
		(109620)	(124350)

The standard error is reported in parentheses below the mean.
TH - teaching hospital.

Table 3: Variable definitions, means and standard errors - Primary Care Centres (PCC)

Definition	Sample statistics					
	All PCC			Teaching PCC		
	Mean	Min	Max	Mean	Min	Max
Physicians (number)	22 (18.24)	2	116	35 (18.33)	6	116
Residents (number)	2 (2.68)	0	16	4 (2.92)	1	16
Nurses (number)	21 (14.36)	2	112	30 (15.53)	8	112
Costs (M€)	6.87M€ (5.06M€)	0.65M€	33.06M€	10.08M€ (5.16M€)	1.84M€	33.06M€
Outpatients (number)	82,026 (68,356)	8,210	414,854	126,447 (69,489)	17,427	414,854
SAP episodes (number)	16,253 (16,260)	0	120,811	18,686 (19,497)	0	120,811
Exams (number)	1,835 (5,484)	0	48,416	2,328 (7,077)	0	48,416
Age ≤ 18 (% of population)	18.8 (3.4)	0.15	27.9	20.0 (3.22)	0.15	27.9
Age ≥ 65 (% of population)	21.8 (7.1)	0.28	42.7	17.8 (5.04)	0.28	31.9
Average wage - physicians	56,669€ (16,805€)	19,579€	164,380€	50,710€ (10,078€)	19,579€	80,700€
Average wage - nurses	22,065€ (4,968€)	12,306€	48,854€	21,158€ (4,205€)	12,306€	48,854€
Teaching PCC	41% (0.49)					
		N=292			N=120	

The standard error is reported in parentheses below the mean.
SAP episodes - non-scheduled (emergency) visits to the primary care centre.
Average wage - physicians includes the wage paid to residents.

Table 4: Variable definitions, means and standard errors - primary care centres (contd.)

Code	Definition	Sample statistics	
		All PCC	PCC
D 3Q Tphys	==1 if Teaching Primary Care Centre and belongs to 3^{rd} quartile of physicians	0.15 (0.36)	0.37 (0.48)
D 4Q Tphys	==1 if TPCC and belongs to 4^{th} quartile of physicians	0.22 (0.41)	0.53 (0.50)
R 1Q phys	Residents * belongs to 1^{st} quartile of physicians	0.01 (0.12)	0.02 (0.18)
R 2Q phys	Residents * belongs to 2^{nd} quartile of physicians	0.05 (0.28)	0.13 (0.42)
R 3Q phys	Residents * belongs to 3^{rd} quartile of physicians	0.41 (1.23)	1.01 (1.76)
R 4Q phys	Residents * belongs to 4^{th} quartile of physicians	1.13 (2.59)	2.76 (3.45)

The standard error is reported in parentheses below the mean.
Tphys stands for being a teaching institution and belonging to the Q^{th} quartile of the distribution of physicians

SRS♯	All PCC		Teaching PCC		SRS♯	All PCC		Teaching PCC	
	Freq	Percent	Freq	Percent		Freq	Percent	Freq	Percent
Aveiro	19	6.51%	10	8.33%	Portalegre	15	5.14%	3	2.50%
Beja	14	4.79%	2	1.67%	Porto	17	5.82%	17	14.17%
Braga	15	5.14%	6	5.00%	Santarem	22	7.53%	6	5.00%
Braganca	12	4.11%	2	1.67%	Setúbal	20	6.85%	10	8.33%
Castelo Branco	11	3.77%	2	1.67%	Viana	11	3.77%	6	5.00%
Coimbra	22	7.53%	12	10%	Vila Real	16	5.48%	4	3.33%
Guarda	14	4.79%	3	2.50%	Viseu	8	2.74%	5	4.17%
Leiria	17	5.82%	11	9.17%	Evora	15	5.14%		0.83%
Lisboa	44	15.07%	20	16.67%					

♯ SRS - Sub-Regional Health Administration; Regional Health Administration Algarve was missing from the data.

There are many hospitals which accept residents for training (75%), but not so many teaching primary care centres (41%). The teaching status and dimension are positively correlated.[19] Teaching activities have here the meaning of training residents. We are not concerned in this work with classroom teaching and the extra costs of university hospitals (though we do control for university hospitals in the estimation procedure). The same happens to the number of residents and the expenditure level. On average, teaching institutions have higher cost and output (outpatient visits, inpatient discharges and emergency room episodes) levels. One needs to account for the asymmetric distribution of costs (see Figure 1), when choosing the most suitable estimation techniques. The variable Residents has the same type of distribution.

Insert Figure 1 and 2 - Total costs - Kernel density

5.2 Methodology

We apply two alternative estimation methods to equation (7) - heteroskedasticity consistent-OLS and robust regression - to control for the characteristics of the data and check robustness of main results about the magnitude of net training costs across different estimation techniques. If the results turn out to be consistent across the estimations methods, we have a reliable estimate of the impact of the fixed factor residents on the institution's cost structure. We have assumed the cost function to be Cobb-Douglas. The same approach was followed by several recent studies, including Farsi and Filippini (2008) for Switzerland, Puig-Junoy and Ortun (2003) for Spain and Menezes et al. (2006) for the Portuguese case. The use of more flexible functional forms would consume degrees of freedom and introduce collinearity issues, which are a concer here. Accounting for non-linearities of some effects is done using some interaction terms.

By applying robust regression to the data, we address the potential role of outliers in the data. If we restricted estimation to heteroskedascity-consistent OLS, atypical observations could affect the accuracy of the expected conditional mean

[19]Hospitals' dimension is measured by the number of beds. For primary care centres, we resort to the number of physicians.

estimates, either over or underestimating the impact of the covariates on the dependent variable. When we resort to robust regression,[20] more weight is given to the information contained on the more typical observations. The iterative process stops when the estimates converge to some parameter estimate.

Another alternative would be to estimate a stochastic cost frontier, to take into account cost function differences due to heterogeneity in the institutions' efficiency levels. Two institutions with the same inputs might produce different outputs, but that can be due to inefficiency issues or to some unobservable random process. When we estimate a stochastic frontier, we assume the error term of the equation to be composed of two distinct variables, one of which is the efficiency component. Thus, this estimation procedure removes the effect of the more inefficient observations on the parameter estimates.[21] However, since we are more interested in the cost effect than on efficiency issues, and given that parameter estimates are similar to the ones obtained in the heteroskedasticity consistent-OLS estimation procedure, stochastic frontier estimates are available in the Appendix, allowing us to focus on the OLS and robust estimation results.

We used the full set of output variables and controls, and then run a regression including the variables with significant coefficients, to check for the stability of parameter estimates.[22] The dependent variable is total costs. Along with the number of residents, we have included a set of variables to capture both a size effect and the effect of economies of scale in the number of residents.

Combining equations (5) and (6), we can expect an increasing cost effect of the number of residents, i.e., larger hospitals face a higher impact on costs. This effect is captured by including as covariates both the quadratic term of Residents and the interaction terms between the quartiles of the size distribution and the number of Residents. We are assuming that, on average, the impact of training one more resident depends on the size of the institution. As an example, it is clear to see that the effect on larger hospitals, i.e., the ones belonging to the upper

[20] See in Fox and Long (1990), the chapter by Berk on robust regression (pp. 292-394), for an overview of this estimation method.

[21] To estimate the inefficiency term of the stochastic frontier, we have to assume a parametric form for the distribution of the term (exponential or the half-normal distribution). See Kumbhakar and Lovell for further details on cross-section cost frontier models.

[22] Full estimates are available in the Appendix. Standard errors and significance levels are as shown in all tables.

quartile of the capacity distribution (number of beds), is most probably different from the average impact on smaller hospitals. We have also included interaction terms between the three types of labor input, since the marginal impact of residents on the cost structure also depends on the number of physicians and nurses working at the hosting institution.

The set of covariates included in the estimation of cost effects for each dataset differ. Initial covariates for hospitals' dataset include output measures - outpatient visits, inpatient discharges and emergency room episodes (ER) -, the case mix index to account for disease complexity, and dummy variables for Medical Schools, the change in management rules,[23] the type of hospital: Central hospitals – large hospitals and with high intensity of technology, District hospitals - medium-sized hospitals, or District Level 1 hospitals – low differentiation, small units, and the Regional Health Administration (RHA), along with two yearly dummies (2003 and 2004).

The initial model applied to the primary care centres (PCC) dataset includes output measures - scheduled and non-scheduled visits (termed SAP episodes) - and the demographic distribution of the population, captured by the percentage of population aged below 18 or above 65 years old, as well as the average wage paid to both physicians and nurses, and the Sub-Regional Health Administration (SRS).[24]

6 The training costs in hospitals

Hospitals' cost function estimates are shown in Tables 5 and 6.[25]

[23]See Gouveia et al. (2006) for the details on this process. Changes concerned mostly financing, budget management and human resources, including major differences in the type of contract between the hospital and the employee.

[24]The SRS hosts the residency programmes and determines how are the residents to be allocated to the primary care centres under its jurisdiction. It is also responsible for the funding of these programmes, together with the payment schemes and the budget of each primary care centre.

[25]All continuous variables are in the logarithmic form, except for the Residents variable. The referees suggested different ways to deal with non-linearities of effects. Further work on the different possibilities suggested by the both referees and on other possible treatments of non-linear effects lead to adoption of the following models.

Table 5: Hospitals - total cost function estimation

	OLS		Robust	
Variable	Full	Sign coef	Full	Sign coef
Residents	0.004**	0.004**	0.003**	0.003*
	(0.001)	(0.001)	(0.001)	(0.001)
Residents^2	0.010*	0.010*	0.010†	0.009†
($\times$1000)	(0.000)	(0.000)	(0.000)	(0.000)
R 1Q beds	-0.012*	-0.011†	-0.009	
	(0.006)	(0.005)	(0.006)	
R 2Q beds	-0.001		-0.002	
	(0.002)		(0.002)	
R 3Q beds	-0.002**	-0.002**	-0.002*	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)
Residents$\times$nurses	-0.005**	-0.005**	-0.005*	-0.004*
($\times$1000)	(0.000)	(0.000)	(0.000)	(0.000)
Residents$\times$physicians	-0.004**	-0.004**	-0.004†	-0.003†
($\times$1000)	(0.000)	(0.000)	(0.000)	(0.000)
Physicians$\times$nurses	0.002**	0.002**	0.002**	0.002**
($\times$1000)	(0.000)	(0.000)	(0.000)	(0.000)
Outpatients	-25.532**	-25.618**	-19.891**	-19.315**
	(5.750)	(0.326)	(5.767)	(5.510)
Outpatients^2	2.452**	2.454**	1.914**	1.845**
	(0.554)	(5.751)	(0.553)	(0.529)
Outpatients^3	-0.077**	-0.077**	-0.060**	-0.057**
	(0.018)	(0.553)	(0.018)	(0.017)
Discharges	-11.479**	-11.312**	-10.565**	-10.743**
	(2.699)	(0.013)	(2.646)	(2.481)
Discharges^2	1.442**	1.422**	1.326**	1.350**
	(0.332)	(0.018)	(0.326)	(0.304)
Discharges^3	-0.058**	-0.057**	-0.053**	-0.054**
	(0.013)	(2.646)	(0.013)	(0.012)
ER episodes	-0.004		-0.001	
	(0.008)		(0.008)	
Case-mix index	0.348**	0.369**	0.366**	0.422**
	(0.064)	(0.058)	(0.056)	(0.047)
D SA	0.015		0.034	
	(0.038)		(0.036)	
Medical School	-0.002		0.029	
	(0.044)		(0.036)	
N	202	202	202	202
R^2	0.979	0.979		
P-value restr	0.828		0.713	

Significance levels: $\dagger$: 10% $*$: 5% $**$: 1%

The standard error is reported in parentheses below parameter estimates.

Notes: Full - regression including all the covariates;

Sign coef - regression including only the covariates with significant coefficient in the full regression;

P-value restriction - P-value of the F-test on the coefficients of the covariates omitted in the restricted model being zero.

Table 6: Hospitals - total cost function estimation (contd.)

	OLS		Robust	
Variable	Full	Sign coef	Full	Sign coef
D 2003	0.077*	0.081**	0.047	0.053*
	(0.035)	(0.030)	(0.029)	(0.026)
D 2004	0.080*	0.084**	0.079**	0.087**
	(0.033)	(0.029)	(0.029)	(0.027)
RHA Alentejo	0.147**	0.140**	0.104†	0.099†
	(0.050)	(0.046)	(0.058)	(0.055)
RHA Algarve	0.067		0.034	
	(0.054)		(0.069)	
RHA Centro	-0.084	-0.090†	-0.167**	-0.179**
	(0.054)	(0.049)	(0.034)	(0.032)
RHA Norte	-0.131**	-0.137**	-0.171**	-0.175**
	(0.044)	(0.040)	(0.036)	(0.034)
Level 2	-0.156**	-0.148**	-0.128**	-0.141**
	(0.046)	(0.042)	(0.049)	(0.043)
Level 1	-0.308**	-0.298**	-0.290**	-0.283**
	(0.066)	(0.060)	(0.063)	(0.058)
Constant	132.523**	132.538**	110.599**	109.486**
	(20.613)	(20.594)	(19.418)	(18.603)
N	202	202	202	202
R^2	0.979	0.979		
P-value restr	0.828		0.713	

Significance levels: † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.

Notes: Full - regression including all the covariates;

Sign coef - regression including only the covariates with significant coefficient in the full regression;

P-value restriction - P-value of the F-test on the coefficients of the covariates omitted in the restricted model being zero.

The overall marginal effect of the variable Residents needs to be computed using parameter estimates of both the number of residents and the interaction terms included in the regression (this is carried out in Section 8 below). For the moment, we can say that, on average, adding on resident to the house staff increases costs, but relatively large hospitals are able to save costs by doing so. The higher the number of physicians and nurses, the lower the costs of hosting residents, caeteris paribus. It is possible to interpret from Table 5 that for a hospital belonging to the first quartile of the distribution of the number of beds, adding one resident to the house staff increases costs by 0.001%. However, and since elasticities are complex to compute due to the interaction terms, we will focus on measuring the marginal cost effect of Residents. This effect includes all the necessary adjustments to host both stages of medical training, foundation and specialty training.

The results are consistent across the estimation methods. The estimates are in line with the existing literature on hospital cost functions, and we will not discuss them in detail here to focus our attention on the impact of residents on costs.[26] Outpatient visits and outpatient discharges are the main cost drivers. ER episodes do not bear a systematic relationship to cost, as they vary considerably across hospitals. The larger the hospital (positively correlated with the teaching status), the more significant is the impact. Since a fraction of them result in admissions to the hospitals or outpatient visits, part of the cost effect of ER is captured by the former variables. Central hospitals (taken as the baseline) have higher costs than the other hospitals, as we would expect. It seems that the case-mix index does not capture all differences in the complexity of cases / severity of patients. Hospitals facing more complicated cases (proxied by the case-mix index) are also more costly. The costs vary across the country, being lower in the north (RHA Norte) than in the southern regions (RHA LVT, the baseline, but also Alentejo and Algarve).

7 The training costs in Primary Care Centres

The Family Practice/GP training programme is similar to the specialty training programmes. Residents are assigned to a Sub-Regional Health Administration, which allocates candidates to Primary Care Centres (PCC) according to the availability

[26]See the book by Jacobs, Smith and Street (2006) for examples of such cost functions.

of supervising physicians.

The estimation results are shown in Table 7.[27]

Table 7: Primary Care Centres - total cost function estimation

	OLS		**Robust**	
Variable	Full	Sign coef	Full	Sign coef
R 2Q physicians	-0.078**	-0.060**	-0.082**	-0.073*
	(0.023)	(0.023)	(0.030)	(0.029)
R 3Q physicians	-0.013		-0.011	
	(0.008)		(0.008)	
R 4Q physicians	-0.003		-0.003	
	(0.005)		(0.006)	
Residents×nurses	0.0002*	0.0001**	0.0002†	0.0001†
	(0.0000)	(0.0000)	(0.0001)	(0.0001)
Scheduled visits	0.863**	0.857**	0.861**	0.865**
	(0.021)	(0.020)	(0.016)	(0.015)
SAP episodes	0.017**	0.018**	0.014**	0.013**
	(0.003)	(0.003)	(0.002)	(0.002)
Exames	0.001		0.003	
	(0.002)		(0.002)	
Age $\leq$ 18	-0.011†	-0.014**	-0.007	
	(0.006)	(0.005)	(0.004)	
Age $\geq$ 65	0.001		0.005*	0.006**
	(0.003)		(0.002)	(0.002)
w_1	0.103		0.051	
	(0.067)		(0.048)	
w_3	0.154*	0.169**	0.169**	0.197**
	(0.064)	(0.059)	(0.048)	(0.047)
Constant	-10.278**	-9.181**	-9.982**	-9.898**
	(0.824)	(0.666)	(0.738)	(0.522)
(...)				
N	292	292	292	292
R^2	0.961	0.960		
P-value restr	0.562		0.108	

Significance levels : † : 10% $*$: 5% $**$: 1%

The standard error is reported in parentheses below parameter estimates.

Notes: Full - regression including all the covariates;

Sign coef - regression including only the covariates with significant coefficient in the full regression.

[27] The variable Residents was not included in the estimation due to collinearity. Summing the variables Residents and R 2Q phys to R 4Q phys yields a column of ones. We chose to take the interaction term with the first quartile as the baseline, and that is why this variable isn't listed in the estimation results as well.

Once again, the marginal effect of residents on costs varies according to the size of the hosting institution. Primary Care Centres with less physicians benefit more from training one extra resident. However, the impact of residents on costs increases with the number of nurses. The overall marginal effect could be positive or negative, but we will see in Section 8 that the benefits more than compensate the costs.

Most of the effects are consistent between heteroskedasticity consistent-OLS and robust regression estimates. Scheduled visits are the main cost driver, and average wages have a strong positive effect on costs. Demographic effects are essentially similar across the models. If we focus on the conditional mean (OLS), we infer that the higher the proportion of population aged below 18 years old, the lower the costs. However, if we constrain the influence of outliers in the data, by using robust regression, the older the population (higher percentage of population aged above 65 years old), the higher the costs, which is the same as saying that younger populations are associated with lower primary care costs. Costs are higher in the capital (Lisbon) than in most of the SRS.[28]

8 The net costs of medical training

In this Section, we use the parameter estimates obtained above to compute the average marginal net cost effect of medical training. The first question that arises is whether teaching residents increases costs, and if it does, by how much. Table 8 provides the answer to this question.[29] In the second column we computed the average marginal effect of being a teaching institution, which is the center of the confidence interval presented in the following columns. This value is also shown as the percentage of average costs of all institutions.

[28]See Appendix for the full estimates (Tables 18 and 19). We have omitted SRS parameter estimates to focus on the effects we are most concerned on.

[29]See Appendix - Section C for the estimation results of the cost effect of the teaching status.

Table 8: Teaching costs

	Hospitals				Primary Care Centres			
	Average	Conf.Int. 95%		% Costs	Average	Conf.Int. 95%		% Costs
OLS	11,761m€	9,442m€	14,080m€	2.24%	196m€	136m€	257m€	1.97%
Robust	7,985m€	6,339m€	9,631m€	1.58%	196m€	140m€	252m€	1.59%

On average, a teaching hospital's expenditure level is around 2% higher than the average cost level of all hospitals. The same type of effect occurs when we look at primary care centres. We derived these results from the estimates presented in the Appendix - Section C.

However, we can go one step further. How much does it cost to train one more resident? What is the net cost (or benefit) of adding one Resident to the house staff?[30] In fact, if an institution trains one more resident, it's costs will decrease, on average. This effect is due to the benefit arising at the medium sized hospitals.

To arrive to this conclusion, a first step is to compute the average effect of adding one resident to the house staff (Table 9, column (1)). To compute the net effect, we subtracted from this value the reference annual wage for a resident (column (2)). Table 9 summarizes the results for each estimation method and type of institution (hospital and primary care centre).

[30]The net cost effect is defined as the difference between the average marginal cost effect of residents and the reference annual wage paid to residents (25,540€).

Table 9: Teaching costs - net effect

	Hospitals							
	All hospitals				Teaching hospitals			
	(1)	(2)	Conf.Int. 95%		(1)	(2)	Conf.Int. 95%	
OLS	11,482€	-14,058€	-34,451€	6,335€	25,716€	-176€	-26,502€	26,854€
Robust	1,943€	-23,297€	-41,339€	-5,855€	-913€	-26,453€	-50,050€	-2,856€

	Primary care centres							
	All primary care centres				Teaching primary care centres			
	(1)	(2)	Conf.Int. 95%		(1)	(2)	Conf.Int. 95%	
OLS	-26,292€	-51,832€	-66,250€	-37,414€	23,088€	-2,452€	-23,591€	18,687€
Robust	-35,830€	-61,370€	-78,513€	-44,227€	21,300€	-4,240€	-26,603€	18,123€

(1) average marginal effect
(2) net effect = average marginal effect - reference annual wage (resident)

By focusing on the robust regression estimates, we can state that training one more Resident increases hospitals' costs by 1,943€, on average. The net cost effect is then negative, meaning that if we subtract the wage paid to the resident, costs decrease by 23,297€. The effect is slightly higher (-26,453€) if we restrict the sample to teaching hospitals. In sum, the net cost effect of residents is similar to the wage paid.

When we focus at primary care centres, the effect is higher. On average, adding one Resident to the house staff decreases costs by 35,830€(Table 10). It is a large effect, motivated by the coefficient related to the primary care centres with a relatively low number of physicians.

We are also interested on the relative effect of medical training on costs, i.e., we want to understand if the hospital or primary care centre faces a large impact on costs or if the relative amount is so small that the impact is nearly negligible. Table 10 presents the net effects computed previously as a proportion of total costs, house staff expenditure, and resident and physician's wage.

Table 10: Teaching costs - net effect

	Hospitals							
	All hospitals				Teaching hospitals			
	Net effect	(1)	(2)	(3)	Net effect	(1)	(2)	(3)
OLS	-14,058€	-55.0%	-0.050%	-0.027%	176€	0.7%	0.001%	-0.021%
Robust	-23,597€	-92.4%	-0.083%	-0.045%	-26,453€	-103.6%	-0.076%	-0.011%

	Primary Care Centres (PCC)							
	All PCC				Teaching PCC			
	Net effect	(1)	(4)	(3)	Net effect	(1)	(4)	(3)
OLS	-51,832€	-202.9%	-111.8%	-0.755%	-2,452€	-9.6%	-5.459%	-0.024%
Robust	-61,370€	-240.3%	-132.3%	-0.893%	-4,240€	-16.6%	-9.440%	-0.042%

(1) percentage of resident's wage
(2) percentage of house staff expenditure
(3) percentage of total costs
(4) percentage of physician's wage

Training one more specialist decreases on average a hospital's expenditure level by 0.05% (robust regression parameter estimates), on average. The benefit is lowered to 0.01% if we restrict to teaching hospitals, due to the proportion of teaching units in the fourth quartile of the capacity distribution.[31]

Overall, benefits from training residents seem to occur at both primary care centres and hospitals, being stronger in the former. At the worst scenario, they seem to be cost neutral from the point of view of the health care hosting institution.

Residents are being paid below their true productivity, on average (Table 10, column (1)). Suppose the reference wage of a Resident was increased by 50% - any institution (hospital or primary care centre) would still face a cost reduction by training another Resident. Teaching primary care centres benefit less than the average, since many larger PCC host residents, and in the case of GP training, smaller institutions benefit more from medical training.

9 A complementary view

The quality of data is always a debatable issue and our case is not different. There is strong variation across health care providers, be it hospitals or primary care centres. Since our empirical statistical analysis is deeply rooted in the nature of

[31]See Section 6.

labor substitution between residents and senior doctors, there is the danger that our assumptions on this may be leading the results.

To check on the issue, interviews with residents were conducted, where a description of the typical working week of a resident was sought. The interviews were conducted as a cross check for the estimation results. Four of the interviews were scheduled and lasted between 1 hour and 1,5 hours. One of the residents was enrolled in a GP specialty programme, and the others were enrolled in inpatient care specialties. Six other interviews were conducted without scheduling the interview. In each of them, strict confidentiality was ensured. In particular, we were interested in identifying time lost by senior doctors on training as well as situations where residents' activities replaced those of senior doctors.

According to our sample of residents, their 42 hours schedule can be divided into five tasks: 12 hours are spent in emergency room shifts (they can devote more than 12 hours to emergency room, but they are paid extra for it); paper work amounts to 10 hours (which would have to be done by senior doctors in the absence of residents), including writing clinical reports and patient histories; 8 hours are spent with the supervisor; studying the materials asked by the supervisor takes up to 5 hours; residents spend 7 hours per week visiting patients and talking to patients' families. It is clear residents take up the bureaucratic part of the job, leaving their supervisor with some extra available time, even taking into account the time they have to spend with the student.

Residents' work has some drawbacks. Technically, they are not as good as senior doctors, above all because of the extra time and resources (mostly diagnosis procedures) residents spend when treating patients. However, much of this difference depends on the chosen specialty. Globally, the total effect of residents' work benefits the institution, either directly (work) or indirectly (supervisors can spend extra time providing health care, instead of doing paper work).

By being so, having residents learning at one's institution is a way of enhancing the workload distribution among the different types of labour comprised by the house staff. Therefore, the qualitative information is in line with the econometric results obtained earlier.

10 Concluding remarks

Medical training is a lengthy and complex process, involving a number of players - hospital or primary care centres, physicians, nurses, providers, professors and students. The purpose of the paper is to assess the costs and benefits to the institution that hosts a residency program.

To do so, one has to consider residents as a specific input, able to perform both physician and nurse staff work. However, the performance is possibly not as efficient as if it were nurses or physicians to provide care to patients. The presence of this type of resource may well influence not only the level but also the structure of the institution's costs.

In order to address this issue, we estimated the impact of residents on Portuguese hospitals and primary care centres. The analysis is possible due to the specificities of the Portuguese Residency programme. The results indicate that providing medical training decreases costs (above the wage of the resident) by a relatively small amount. This means that claims from hospital and primary care centres' managers that teaching consumes resources (time of physicians) are largely compensated for by the activity with which residents contribute to the institution. The effect is stronger in the case of general practitioner training. Our results have strong, and important, implications. Given that residents are a fixed exogenous factor and that organization of labor work at the health care institution adjusts to take advantage of their presence, there should be no cash transfer to a hosting institution, either in the form of a subsidy or tuition fee. At most, their wage should be compensated by transfers from the National Health Service.

A final word to a couple of caveats. Firstly, the quality of data is always an issue, namely for costs of decision-making units (hospitals or primary care centres). Second, the short time span precludes the exploration of the panel data nature of the series. We expect that both shortcomings can be addressed in future research.

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A Data sources

Table 11: Data sources

Source	Variables
Ministry of Health (2002/2005)	Physicians, Residents, Nurses
Hospitals' Annual Report and Accounts (Hospitals - 2002/2004)	Total costs, House staff expenditures, outpatient visits, discharges, emergency room episodes, case-mix index, beds, Medical School, type of hospital
Regional Health Administrations' Tableaux de Bord (Primary Care Centres - 2005)	Costs, outpatients, SAP episodes, Exams, age, average wage (physicians and nurses), sub-regional health administration

B Stochastic frontier estimation

Table 12: Hospitals - total cost function estimation

	OLS		Frontier		Robust	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
Residents	0.004**	0.004**	0.004**	0.004**	0.003**	0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Residents^2	0.010*	0.010*	0.010†	0.010†	0.010†	0.009†
(×1000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R 1Q beds	-0.012*	-0.011†	-0.011†		-0.009	
	(0.006)	(0.005)	(0.007)		(0.006)	
R 2Q beds	-0.001		-0.001		-0.002	
	(0.002)		(0.002)		(0.002)	
R 3Q beds	-0.002**	-0.002**	-0.002*	-0.002*	-0.002*	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Physicians×residents	-0.004**	-0.004**	-0.004†	-0.003†	-0.004†	-0.003†
(×1000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Physicians×nurses	0.002**	0.002**	0.002**	0.002**	0.002**	0.002**
(×1000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Nurses×residents	-0.005**	-0.005**	-0.005*	-0.005*	-0.005*	-0.004*
(×1000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Outpatients^2	2.452**	2.454**	2.477**	2.449**	1.914**	1.845**
	(0.554)	(0.553)	(0.577)	(0.564)	(0.555)	(0.529)
Outpatients^3	-0.077**	-0.077**	-0.078**	-0.076**	-0.060**	-0.057**
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.017)
Discharges^2	1.442**	1.422**	1.451**	1.462**	1.326**	1.350**
	(0.332)	(0.326)	(0.334)	(0.325)	(0.322)	(0.304)
Discharges^3	-0.058**	-0.057**	-0.058**	-0.059**	-0.053**	-0.054**
	(0.013)	(0.013)	(0.013)	(0.013)	(0.013)	(0.012)
Outpatients	-25.532**	-25.618**	-25.806**	-25.698**	-19.891**	-19.315**
	(5.750)	(5.751)	(6.002)	(5.882)	(5.767)	(5.510)
Discharges	-11.479**	-11.312**	-11.553**	-11.581**	-10.565**	-10.743**
	(2.699)	(2.646)	(2.729)	(2.652)	(2.631)	(2.481)
N	202	202	202	202	202	202
R^2	0.9727	0.9724				
P-value restr	0.815		0.351		0.190	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.

Table 13: Hospitals - total cost function estimation (contd.)

	OLS		Frontier		Robust	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
ER episodes	-0.004		-0.003		-0.001	
	(0.008)		(0.008)		(0.008)	
Case-mix index	0.348**	0.369**	0.345**	0.388**	0.366**	0.422**
	(0.064)	(0.058)	(0.058)	(0.051)	(0.056)	(0.047)
D SA	0.015		0.017		0.034	
	(0.038)		(0.037)		(0.036)	
Medical School	-0.002		-0.001		0.029	
	(0.044)		(0.038)		(0.036)	
D 2003	0.077*	0.081**	0.075*	0.079**	0.047	0.053*
	(0.035)	(0.030)	(0.030)	(0.028)	(0.029)	(0.026)
D 2004	0.080*	0.084**	0.078*	0.084**	0.079**	0.087**
	(0.033)	(0.029)	(0.031)	(0.028)	(0.029)	(0.027)
RHA Alentejo	0.147**	0.140**	0.154*	0.154*	0.104†	0.099†
	(0.050)	(0.046)	(0.062)	(0.060)	(0.058)	(0.055)
RHA Algarve	0.067		0.071		0.034	
	(0.054)		(0.072)		(0.069)	
RHA Centro	-0.084	-0.090†	-0.085*	-0.098**	-0.167**	-0.179**
	(0.054)	(0.049)	(0.036)	(0.034)	(0.034)	(0.032)
RHA Norte	-0.131**	-0.137**	-0.130**	-0.135**	-0.171**	-0.175**
	(0.044)	(0.040)	(0.038)	(0.036)	(0.036)	(0.034)
Level 2	-0.156**	-0.148**	-0.155**	-0.159**	-0.128**	-0.141**
	(0.046)	(0.042)	(0.051)	(0.046)	(0.049)	(0.043)
Level 1	-0.308**	-0.298**	-0.304**	-0.292**	-0.290**	-0.283**
	(0.066)	(0.060)	(0.066)	(0.062)	(0.063)	(0.058)
Constant	132.52**	132.54**	133.64**	133.74**	110.60**	109.49**
	(20.613)	(20.594)	(20.290)	(19.973)	(19.418)	(18.603)
N	202	202	202	202	202	202
R^2	0.9727	0.9724				
P-value restr	0.815		0.351		0.190	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.

Table 14: Primary Care Centres - total cost function estimation

	OLS		**Frontier**		**Robust**	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
R 2Q physicians	-0.078**	-0.060**	-0.076*	-0.074*	-0.082**	-0.073*
	(0.023)	(0.023)	(0.033)	(0.032)	(0.030)	(0.029)
R 3Q physicians	-0.013		-0.013		-0.011	
	(0.008)		(0.008)		(0.008)	
R 4Q physicians	-0.003		-0.003		-0.003	
	(0.005)		(0.007)		(0.006)	
Residents×nurses	0.0002*	0.0001**	0.0002		0.0002†	0.0001†
	(0.0000)	(0.0000)	(0.0001)		(0.0001)	(0.0001)
Scheduled visits	0.863**	0.857**	0.865**	0.872**	0.861**	0.865**
	(0.021)	(0.020)	(0.018)	(0.014)	(0.016)	(0.015)
SAP episodes	0.017**	0.018**	0.017**	0.018**	0.014**	0.013**
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Exames	0.001		0.001		0.003	
	(0.002)		(0.003)		(0.002)	
Age $\leq$ 18	-0.011†	-0.014**	-0.011*	-0.013**	-0.007	
	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	
Age $\geq$ 65	0.001		0.001		0.005*	0.006**
	(0.003)		(0.003)		(0.002)	(0.002)
w_1	0.103		0.102†	0.093†	0.051	
	(0.067)		(0.053)	(0.049)	(0.048)	
w_3	0.154*	0.169**	0.154**	0.160**	0.169**	0.197**
	(0.064)	(0.059)	(0.053)	(0.053)	(0.048)	(0.047)
Constant	-10.278**	-9.181**	-10.351**	-10.354**	-9.982**	-9.898**
	(0.824)	(0.666)	(0.814)	(0.760)	(0.738)	(0.522)
(...)						
N	292	292	292	292	292	292
R^2	0.961	0.960				
P-value restr	0.562		0.256		0.108	

Significance levels : † : 10% $*$: 5% $**$: 1%

The standard error is reported in parentheses below parameter estimates.

The variable Residents was not included in the estimation due to collinearity.

C The cost of teaching

We will now focus on the simple teaching cost effect, which can be done by adding an indicator variable of the teaching status to the estimated cost function.

Hospitals' cost function parameter estimates (Table 15) point to a significant impact of teaching on the cost structure. Furthermore, there is a positive relationship between dimension and costs. The effects of the other covariates are similar to the ones obtained in Section 6.

Table 15: Hospitals - total cost function estimation (teaching costs)

	OLS		**Frontier**		**Robust**	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
TH	-0.195**	-0.196**	-0.195**	-0.196**	-0.186**	-0.187**
	(0.053)	(0.053)	(0.064)	(0.064)	(0.058)	(0.058)
TH 2Q beds	0.341**	0.343**	0.341**	0.343**	0.293**	0.268**
	(0.069)	(0.066)	(0.071)	(0.071)	(0.065)	(0.064)
TH 3Q beds	0.388**	0.396**	0.388**	0.396**	0.349**	0.325**
	(0.077)	(0.070)	(0.078)	(0.077)	(0.071)	(0.068)
TH 4Q beds	0.445**	0.467**	0.445**	0.467**	0.385**	0.377**
	(0.085)	(0.083)	(0.087)	(0.086)	(0.079)	(0.077)
Outpatients	0.505**	0.503**	0.505**	0.503**	0.513**	0.510**
	(0.050)	(0.049)	(0.048)	(0.047)	(0.044)	(0.042)
Discharges	-0.487*	-0.505*	-0.487†	-0.505*	-0.618**	-0.697**
	(0.213)	(0.210)	(0.252)	(0.251)	(0.230)	(0.227)
Discharges^2	0.046**	0.047**	0.046**	0.047**	0.053**	0.059**
	(0.012)	(0.012)	(0.015)	(0.014)	(0.013)	(0.013)
ER episodes	0.006		0.006		0.007	
	(0.006)		(0.008)		(0.007)	
Case-mix index	0.390**	0.369**	0.390**	0.369**	0.428**	0.409**
	(0.063)	(0.056)	(0.058)	(0.055)	(0.053)	(0.049)
D SA	-0.017		-0.017		-0.014	
	(0.037)		(0.038)		(0.034)	
Med School	0.014		0.014		0.058	
	(0.048)		(0.039)		(0.035)	
D 2003	0.069*	0.064*	0.069*	0.064*	0.044	
	(0.033)	(0.029)	(0.032)	(0.029)	(0.029)	
D 2004	0.060†	0.054†	0.060†	0.054†	0.065*	0.043†
	(0.034)	(0.031)	(0.032)	(0.030)	(0.029)	(0.023)
RHA Alentejo	0.067		0.067		0.035	
	(0.052)		(0.065)		(0.059)	
RHA Algarve	0.151**	0.143**	0.151†	0.143†	0.098	
	(0.053)	(0.051)	(0.077)	(0.077)	(0.070)	
RHA Centro	-0.087†	-0.094†	-0.087*	-0.094**	-0.158**	-0.184**
	(0.052)	(0.049)	(0.036)	(0.036)	(0.033)	(0.031)
RHA Norte	-0.154**	-0.163**	-0.154**	-0.163**	-0.170**	-0.196**
	(0.036)	(0.033)	(0.036)	(0.035)	(0.033)	(0.0303475)
Level 2	-0.274**	-0.267**	-0.274**	-0.267**	-0.205**	-0.206**
	(0.050)	(0.039)	(0.043)	(0.038)	(0.039)	(0.033)
Level 1	-0.458**	-0.454**	-0.458**	-0.454**	-0.421**	-0.415**
	(0.065)	(0.058)	(0.061)	(0.058)	(0.056)	(0.052)
Constant	12.415**	12.587**	12.413**	12.586**	12.922**	13.348**
	(0.947)	(0.914)	(1.216)	(1.210)	(1.028)	(1.014)
N	202	202	202	202	202	202
R^2	0.976					
P-value restr.	0.314		0.6339		0.194	

Significance levels : † : 10% $*$: 5% $**$: 1%

The standard error is reported in parentheses below parameter estimates.

The results regarding primary care centres show (Table 16) that teaching institutions have higher costs. However, large teaching institutions can overcome this negative effect and and up spending less, on average. Once again, the cost function parameter estimates (Table 16 and 17) are similar to the ones obtained previously (Section 7).

Table 16: Primary Care Centres- total cost function estimation (teaching costs)

	OLS		**Frontier**		**Robust**	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
Teaching PCC	0.076*	0.074*	0.075*	0.071*	0.070*	0.069*
	(0.030)	(0.030)	(0.031)	(0.031)	(0.029)	(0.028)
T 3Q physicians	-0.144**	-0.140**	-0.142**	-0.142**	-0.135**	-0.134**
	(0.049)	(0.048)	(0.051)	(0.051)	(0.047)	(0.046)
T 4Q physicians	-0.093**	-0.093**	-0.093**	-0.095**	-0.082**	-0.080**
	(0.028)	(0.028)	(0.031)	(0.031)	(0.029)	(0.029)
Outpatients	0.862**	0.862**	0.863**	0.867**	0.858**	0.861**
	(0.022)	(0.021)	(0.019)	(0.018)	(0.017)	(0.016)
SAP episodes	0.015**	0.015**	0.015**	0.015**	0.013**	0.012**
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Exams	0.001		0.001		0.003	
	(0.002)		(0.003)		(0.002)	
Age $\leq$ 18	-0.011	-0.011*	-0.011*	-0.011**	-0.006	
	(0.007)	(0.005)	(0.005)	(0.004)	(0.004)	
Age $\geq$ 65	0.001		0.001		0.005†	0.006**
	(0.003)		(0.003)		(0.002)	(0.002)
w_1	0.166*	0.171*	0.165**	0.172**	0.111 *	0.120**
	(0.065)	(0.066)	(0.047)	(0.042)	(0.043)	(0.038)
w_3	0.148*	0.157*	0.148**	0.155**	0.152**	0.156**
	(0.064)	(0.062)	(0.052)	(0.052)	(0.048)	(0.048)
Constant	-10.886**	-11.010**	-10.950**	-11.126**	-10.441**	-10.734**
	(0.797)	(0.755)	(0.762)	(0.703)	(0.698)	(0.631)

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.

Table 17: Primary Care Centres- total cost function estimation (teaching costs) SRS variables

	OLS		Frontier		Robust	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
SRS Aveiro	-0.319**	-0.317**	-0.319**	-0.308**	-0.310**	-0.310**
	(0.036)	(0.032)	(0.043)	(0.038)	(0.040)	(0.035)
SRS Beja	-0.217**	-0.208**	-0.219**	-0.199**	-0.134**	-0.121**
	(0.068)	(0.064)	(0.053)	(0.045)	(0.048)	(0.042)
SRS Braga	-0.181**	-0.179**	-0.181**	-0.170**	-0.171**	-0.196**
	(0.043)	(0.041)	(0.050)	(0.047)	(0.046)	(0.039)
SRS Braganca	-0.111*	-0.102*	-0.107†	-0.088†	-0.106*	-0.098*
	(0.050)	(0.045)	(0.058)	(0.049)	(0.053)	(0.045)
SRS Castelo Branco	-0.049		-0.048		-0.114*	-0.095*
	(0.063)		(0.056)		(0.051)	(0.047)
SRS Coimbra	-0.104**	-0.098**	-0.103*	-0.087*	-0.118**	-0.117**
	(0.036)	(0.033)	(0.042)	(0.036)	(0.039)	(0.033)
SRS Guarda	0.007		0.004		-0.028	
	(0.057)		(0.054)		(0.049)	
SRS Leiria	-0.122**	-0.118**	-0.121*	-0.107*	-0.110*	-0.116 **
	(0.041)	(0.038)	(0.047)	(0.042)	(0.043)	(0.039)
SRS Portalegre	-0.307**	-0.298**	-0.311**	-0.291**	-0.282**	-0.281**
	(0.073)	(0.072)	(0.052)	(0.045)	(0.046)	(0.042)
SRS Porto	-0.189**	-0.187**	-0.189**	-0.181**	-0.172**	-0.192**
	(0.048)	(0.045)	(0.048)	(0.045)	(0.045)	(0.039)
SRS Santarem	-0.373**	-0.363**	-0.372**	-0.354**	-0.374**	-0.363**
	(0.039)	(0.035)	(0.043)	(0.036)	(0.040)	(0.033)
SRS Setúbal	-0.005		-0.005		0.000	
	(0.036)		(0.041)		(0.038)	
SRS Viana	-0.085*	-0.076†	-0.085†		-0.088†	-0.072†
	(0.041)	(0.040)	(0.051)		(0.047)	(0.043)
SRS Vila Real	-0.158**	-0.155**	-0.157**	-0.143**	-0.154**	-0.159**
	(0.046)	(0.042)	(0.047)	(0.041)	(0.043)	(0.038)
SRS Viseu	-0.314**	-0.310**	-0.312**	-0.298**	-0.309**	-0.321**
	(0.049)	(0.045)	(0.063)	(0.057)	(0.058)	(0.051)
SRS Évora	-0.184**	-0.173**	-0.187**	-0.167**	-0.195**	-0.184**
	(0.066)	(0.065)	(0.049)	(0.043)	(0.044)	(0.040)
N	292	292	292	292	292	292
R^2	0.962	0.962				
P-value restr	0.974		0.731		0.399	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.

D Estimation results - Primary Care Centres

Table 18: Primary Care Centres - total cost function estimation

	OLS		Frontier		Robust	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
R 2Q physicians	-0.078**	-0.060**	-0.076*	-0.074*	-0.082**	-0.073*
	(0.023)	(0.023)	(0.033)	(0.032)	(0.030)	(0.029)
R 3Q physicians	-0.013		-0.013		-0.011	
	(0.008)		(0.008)		(0.008)	
R 4Q physicians	-0.003		-0.003		-0.003	
	(0.005)		(0.007)		(0.006)	
Residents×nurses	0.0002*	0.0001**	0.0002		0.0002†	0.0001†
	(0.0000)	(0.0000)	(0.0001)		(0.0001)	(0.0001)
Scheduled visits	0.863**	0.857**	0.865**	0.872**	0.861**	0.865**
	(0.021)	(0.020)	(0.018)	(0.014)	(0.016)	(0.015)
SAP episodes	0.017**	0.018**	0.017**	0.018**	0.014**	0.013**
	(0.003)	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)
Exames	0.001		0.001		0.003	
	(0.002)		(0.003)		(0.002)	
Age $\leq$ 18	-0.011†	-0.014**	-0.011*	-0.013**	-0.007	
	(0.006)	(0.005)	(0.005)	(0.004)	(0.004)	
Age $\geq$ 65	0.001		0.001		0.005*	0.006**
	(0.003)		(0.003)		(0.002)	(0.002)
w_1	0.103		0.102†	0.093†	0.051	
	(0.067)		(0.053)	(0.049)	(0.048)	
w_3	0.154*	0.169**	0.154**	0.160**	0.169**	0.197**
	(0.064)	(0.059)	(0.053)	(0.053)	(0.048)	(0.047)
Constant	-10.278**	-9.181**	-10.351**	-10.354**	-9.982**	-9.898**
	(0.824)	(0.666)	(0.814)	(0.760)	(0.738)	(0.522)
(...)						
N	292	292	292	292	292	292
R^2	0.961	0.960				
P-value restr	0.562		0.256		0.108	

Significance levels : † : 10% $*$: 5% $**$: 1%

The standard error is reported in parentheses below parameter estimates.

The variable Residents was not included in the estimation due to collinearity.

Table 19: Primary Care Centres - total cost function estimation - SRS Variables

	OLS		**Frontier**		**Robust**	
Variable	Full	Sign coef	Full	Sign coef	Full	Sign coef
SRS Aveiro	-0.306**	-0.285**	-0.306**	-0.295**	-0.295**	-0.282**
	(0.035)	(0.029)	(0.044)	(0.039)	(0.040)	(0.035)
SRS Beja	-0.197**	-0.186**	-0.200**	-0.182**	-0.127**	-0.096*
	(0.068)	(0.064)	(0.053)	(0.046)	(0.048)	(0.041)
SRS Braga	-0.190**	-0.166**	-0.189**	-0.160**	-0.181**	-0.197**
	(0.043)	(0.040)	(0.052)	(0.048)	(0.047)	(0.040)
SRS Braganca	-0.064		-0.061		-0.076	
	(0.048)		(0.055)		(0.050)	
SRS Castelo Branco	-0.035		-0.035		-0.119*	
	(0.066)		(0.056)		(0.051)	
SRS Coimbra	-0.084*	-0.086**	-0.084*	-0.080*	-0.102**	-0.096*
	(0.035)	(0.029)	(0.042)	(0.036)	(0.038)	(0.032)
SRS Guarda	0.054		0.049		-0.010	
	(0.066)		(0.051)		(0.046)	
SRS Leiria	-0.110**	-0.110**	-0.109*	-0.101*	-0.098*	-0.101*
	(0.041)	(0.039)	(0.047)	(0.042)	(0.043)	(0.038)
SRS Portalegre	-0.301**	-0.315**	-0.306**	-0.293**	-0.263**	-0.254**
	(0.075)	(0.071)	(0.052)	(0.045)	(0.046)	(0.040)
SRS Porto	-0.150**	-0.138**	-0.151**	-0.136**	-0.130**	-0.149**
	(0.046)	(0.045)	(0.047)	(0.044)	(0.043)	(0.038)
SRS Santarem	-0.372**	-0.339**	-0.371**	-0.352**	-0.369**	-0.333**
	(0.040)	(0.029)	(0.045)	(0.037)	(0.041)	(0.032)
SRS Setubal	0.008		0.008		0.010	
	(0.034)		(0.041)		(0.037)	
SRS Viana	-0.073*	-0.082**	-0.072		-0.080†	-0.059**
	(0.034)	(0.031)	(0.053)		(0.048)	(0.044)
SRS Vila Real	-0.151**	-0.143**	-0.151**	-0.144**	-0.148**	-0.140**
	(0.047)	(0.041)	(0.048)	(0.042)	(0.043)	(0.037)
SRS Viseu	-0.298**	-0.285**	-0.297**	-0.298**	-0.296**	-0.300**
	(0.051)	(0.044)	(0.062)	(0.058)	(0.056)	(0.050)
SRS Evora	-0.191**	-0.197**	-0.193**	-0.174**	-0.204**	-0.183**
	(0.065)	(0.063)	(0.049)	(0.044)	(0.044)	(0.039)
N	292	292	292	292	292	292
R^2	0.961	0.960				
P-value restr	0.562		0.256		0.108	

Significance levels : † : 10% ∗ : 5% ∗∗ : 1%

The standard error is reported in parentheses below parameter estimates.