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Fiscal Federalism

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Postal Address:
Institut d'Economia de Barcelona
Facultat d'Economia i Empresa
Universitat de Barcelona
C/ Tinent Coronel Valenzuela, 1-11
(08034) Barcelona, Spain
Tel.: + 34 93 403 46 46
Fax: + 34 93 403 98 32
ieb@ub.edu
http://www.ieb.ub.edu

EFFECTS OF FISCAL DECENTRALISATION AND ELECTORAL ACCOUNTABILITY ON GOVERNMENT EFFICIENCY EVIDENCE FROM THE ITALIAN HEALTH CARE SECTOR *

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ABSTRACT: Data envelopment analysis and panel data stochastic frontier models are used to evaluate the impact of the 1995 renewal of regional political institutions and the 1998 tax reform (introduction of IRAP) on the efficiency of Italian regional governments. Both methodologies are applied to a longitudinal dataset, including financial and health care data disaggregated at the regional level from 1991 to 2005. Then, efficiency scores for the regional governments are used to examine the evolution of technical efficiency in the Italian health care sector. The final results provide new empirical evidence in support of the findings of recent theoretical models concerning the way in which fiscal decentralization and electoral accountability affect the efficiency of governmental activity.

JEL Codes: H11, H51, H77, I11

Keywords: accountability, DEA, decentralisation, efficiency, health, IRAP, Italy, panel data, stochastic frontier

Francesco Porcelli
Department of Economics
University of Warwick
E-mail: f.porcelli@warwick.ac.uk.

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1 Introduction

The Italian process of decentralisation that began after the financial and political crises of the early 1990s and the renewal of political institutions of those years provide the primary motivation for this paper. In 1995, new regional elections were held under a new electoral law, which replaced the previous proportional system with a new ststem based on majority rule and which also favoured the establishment of a presidential regime in regional governments. Secondly, while health care expenditures, along with part of the decision-making powers, have been allocated at the regional level since the establishment of regions at the end of 1970s, revenues have been characterised by a decentralisation process only during the 1990s. The most important reform occured in 1998 when new regional tax revenues replaced many of the conditional intergovernmental grants. The political renewal that involved all regional governments in 1995 and the 1998 reform of the funding system of the Italian health care sector are two important events that can be used to assess the impact of decentralisation and electoral accountability on government efficiency.

The main intention of both reforms was to increase the accountability of the regional public authorities. Hence, the main question that this paper will attempt to answer is whether the 1998 tax reform, along with the 1995 renewal of political institutions, had any effect on the efficiency of health care sector in Italy. According to the new political economy approach to fiscal decentralisation, some improvements in efficiency should be expected because, when both management and financial responsibility rest in the hands of the same local officials, less information asymmetry should affect the principal agent game between citizens and regional governments. Moreover, given the new electoral system, citizens will have a better opportunity to judge the performance of sub-national officials, thereby motivating the latter to provide better services.

The empirical strategy is to treat the 1995 and 1998 reforms as exogenous policy variations in order to estimate their impact on the efficiency of the health care sector. To that end, each regional government will be treated as a decision making unit that provides health care services. Two main methodologies will be applied - *Data Envelopment Analysis* (DEA) and *Panel Data Stochastic Frontier Models* (SFM). Both methodologies will be applied to the Italian health sector using a longitudinal dataset, including financial and health care data disaggregated at the regional level for the fifteen year period of 1991 - 2005. The results of the empirical models confirm the expected positive effect of both policy variations on government efficiency with both methodologies. However, the 1998 tax reform exhibited an ambiguous and much weaker effect on government efficiency than did the 1995 electoral reform. Further, both methodologies enable the regional governments' technical efficiency in the provision of health care services to be evaluated. In general, the south appears to be less efficient than the rest of the country, and a clear increase in efficiency can be observed only after 1995 all over the country.

The rest of the paper is structured as follows. Section 2 describes the change that interested regional political institutions in 1995 and the main aspects of the 1998 reform of the health care funding system. Section 3 provides a summary of the theoretical and empirical literature on the economic effects of political institutions and decentralisation on the quality of government. The description of the dataset is presented in Section 4 followed by an analysis of the empirical models in Section 5. Finally, Section 6 reports the main results. Section 7 presents the conclusions.

2 1995 regional elections and 1998 tax reform

According to the Italian Constitution there are five tiers of government: metropolitan areas, municipalities, provinces, regions, and central government. Health care is the most important function of regional governments and according to 2005 figures, almost 98% of health care expenditure is allocated at regional level and it represents more than 50% of total regional budget expenditure. In this area central government legislation enacts general principles, and regional governments can pass laws inside this framework.

In February, 1995, two months before the regional elections, the central government introduced a new regional electoral system[1]. This reform completed the renewal that involved the electoral systems of all levels of government.[2] The main issue in the parliamentary debate was the proportion of seats to be assigned by a majority method. This indicated the desire to change the previous simple proportional system to a new system in order to stimulate electoral accountability of regional politicians following the political crisis that involved all levels of governments in the early 1990s.[3] Under the new electoral rules, 20% of the seats in the regional parliaments will be assigned by the majority method, sufficient to guarantee the formation of the government by the winning coalition and to create a bipolar political space. Moreover, under the new electoral system, the names of the candidates, who compete for the presidency, appeared, for the first time, on the ballots as heads of the electoral lists. As a result, beginning in 1995, the form of regional governments evolved towards a presidential regime, although it was only in 1999 that the direct election of the heads of the regional governments was formally introduced.[4]

In 1998 a substantial part of intergovernmental grants earmarked for the health care sector has been replaced by two new regional taxes. First IRAP[5], a value added tax on productive activities that applies to companies, private and public entities and commercial and non-commercial activities. It is levied on the net value of the production derived in each region; its standard rate at present is 3.9% and regional government can increase or decrease it by up to 1% [Longobardi, 2005]. According to 2005 figures IRAP represented 22% of total regional budget revenues. Second a regional additional personal income tax whose amount was around 4% of total regional revenues in 2005. At present its standard tax rate is 0.9% and each regional government can increase it up to 1.4%. In 2005, these two taxes financed almost 40% of total health expenditure. Figure 1 shows the increase of the incidence of regional tax revenues in the total financial resources earmarked for the health sector. At the beginning of the 1990s they accounted for something like 2%, and after 1998 they amounted to something like 50%, a substantial change that can be interpreted as a structural break.

[1] Legge n. 43/1995.

[2] In 1993, the direct election of the mayor and the president of the province revolutionised the local electoral systems. In 1994, after the referendum of the previous year, the election of members of the national parliament was held under a new majority system, which replaced the previous proportional system.

[3] During those years, the entire political class underwent a change as a result of "Tangentopoli", the system of corruption that was uncovered by a nationwide, Italian, judicial investigation of political corruption named "Mani pulite" (Italian for "clean hands"). Mani pulite began in February, 1992 and led to the demise of the so-called First Republic, resulting in the disappearance of the parties that had led the political scene since the post-war period.

[4] Legge Costituzionale n. 1/1999.

[5] Imposta Regionale sulle Attività Produttive (Regional Tax on Productive Activities).

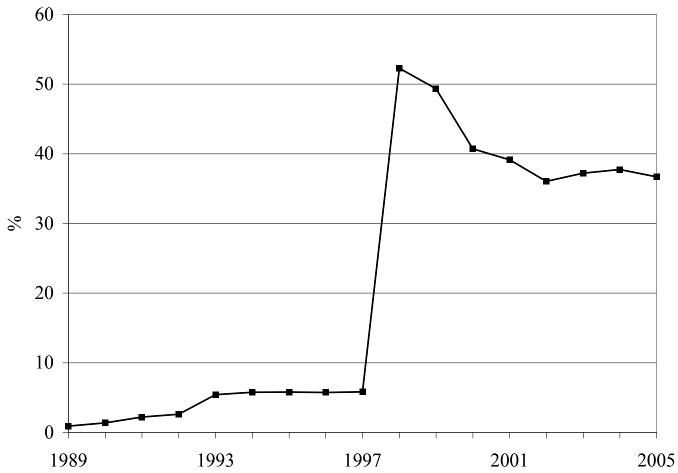


Figure 1: Percentage of regional own tax revenues in relation to total current regional revenues earmarked for health sector, overall average across regions, year 1989-2005. Source ISSiRFA-CNR [2008].

It is important to notice that because of the influence wielded by central government only slight changes have been introduced by regional governments to the standard rates. Therefore, most of the variability registered in the tax revenue across regions can be explained by the "income gap" between the south and the north-central parts of the peninsula rather than by differences in the fiscal polices adopted by regional governments.[6] The average 2005 per capita GDP in the south of the country is less than 60% of the average of that in the north and less than 70% of the average of that in the central part. As a result, scepticism spread about the possibility that the tax reform could stimulate the electoral accountability of local politicians in such a way as to affect positively the efficiency of regional government.

In conclusion it is important to notice that IRAP and the regional additional personal income tax were introduced by central government provision at the same time in all regions. Similarly, the new electoral system was decided at central level, and elections were held on the natural expiry of the regional governments in office. Therefore, the 1998 tax reform as well as the 1995 electoral reform and the subsequent ballot can be considered as exogenous policy variations, i.e. unrelated to the decision-making power of regional governments.

3 Effect of decentralisation and political institutions on government efficiency

[6]According to 2005 figures, revenues produced by the new regional taxes in the northern and central regions financed 48% and 37% respectively of the total health expenditures. In the southern regions, they financed only 23% which means that most of the health care expenditures in the southern regions are covered by grants from the central government. Conversely per capita health expenditure results evenly distributed across the three macro regions, according to 2005 figures 1529, 1673, and 1476 euros respectively in the north, centre and south.

The main argument that this paper seeks to resolve is whether the 1995 new electoral rules and 1998 tax reform have stimulated the accountability of local politicians, which, in turn, might have positively affected the quality of regional governments. Seabright's seminal paper [Seabright, 1996] gives to accountability the precise meaning of *electoral accountability* since it is defined in terms of the probability that welfare levels of a given jurisdiction determine the election of the government. Lockwood [2005], however, remarks that if the concept of accountability is defined broadly, it will be difficult to distinguish it from preference-matching. Therefore, it has been proposed that the concept of accountability be characterised more precisely, either with the degree to which institutions allow the government to divert rents, or with the degree to which institutions allow special interest groups to distort government decision-making by lobbying.[7]

As reported above, the 1995 electoral reform favoured the transition from a proportional system to a majoritarian system, as well as the establishment of a presidential regime. Then, as indicated in Figure 1, the level of fiscal decentralisation increased dramatically after the 1998 tax reform. The literature identifies different mechanisms by which political institutions and fiscal decentralization may stimulate electoral accountability bringing about increased efficiency.

Theoretical models that compare proportional and majoritarian systems (see Persson and Tabellini [2000], Chapters 8 and 9) show that majoritarian systems can affect electoral accountability in both directions, either increasing or decreasing the possibility of rent diversion by politicians. In models of pre-election politics, where candidates are assumed to make binding promises, there is more intense electoral competition among candidates in majoritarian elections. This reduces the possibility of rent diversion by politicians and stimulates their elecoral accountability. Conversely, in the models of post-election politics, where politicians' promises cannot be enforced and the incumbent needs to please only a minimum winning coalition of voters in order to be reappointed, majoritarian elections involve more intense competition only among voters to be included in that minimum winning coalition. This will imply higher rents for politicians that corresponds to less electoral accountability.

With regard to the form of government, the theoretical models that compare presidential and parliamentary regimes (see Persson and Tabellini [2000] chapter 10) show that presidential regimes can cope better with the agency problem between voters and politicians due to the clearer separation of powers. This brings lower taxes and greater accountability. As a result, presidential regimes are unambiguously associated with smaller governments and less waste than parliamentary regimes.

According to the *principal agent models of electoral accountability* (one stream within the literature on the second-generation theory of fiscal federalism), fiscal decentralisation can affect government efficiency in a positive way [Besley and Case, 1995, Besley and Smart, 2007, Bordignon et al., 2004, Hindriks and Lockwood, 2008]. In these models, the electorate are the principals and politicians are the agents. The presence of asymmetric information between them can be seen as the main reason why the government's performance is inefficient. The crucial point here is that fiscal decentralisation can create an incentive to reduce rent diversion and/or the influence of lobbies, leading to a higher probability of re-election through two main forms of competition among local govern-

[7] In the continuation we will consider accountability more in terms of rent diversion, for the lobbing argument you can consider Bardhan and Mookerjee [2000], Bordignon et al. [2003], Redoano [2003] and Ruta [2006].

ments. The first is *tax competition*, which occurs when local governments compete over tax rates in order to attract tax base[8]. The second is *yardstick competition*, which occurs when voters can compare tax policies and levels of public-good provision that have been adopted by officials in other regions with those offered in their own jurisdiction and use their ballots as a vote on the performance of their incumbent, relative to the incumbents in other regions.

Persson and Tabellini [2005] (chapter 7), using a cross-section of around 70 countries, provide empirical evidence of the effect of majoritarian electoral systems and presidential regimes on rent extraction (measured in terms of perceived corruption by public officials) and productivity (measured in terms of labour and total factor productivity). Their results are grenerally in line with the theory. Presidentialism has a negative effect on rent extraction and favours productivity, particularly in the case of greater democracy. Majoritarian systems unambiguously discourage corruption and foster productivity only when associated with a ballot structure that enables the election of a high percentage of legislators outside of the party list.

In most of the recent empirical literature, the effect of fiscal decentralisation is estimated by using a cross-sectional dataset of a wide range of developed and developing countries. Usually, the reduced-form approach is followed. Hence, measures of general government performance (e.g., the perceived corruption or indicators of the output and/or quality of the service in sectors like health care and education) are regressed over measures of fiscal decentralisation like the ratio of local public expenditures over general government expenditures. Most of the empirical evidence attests to the positive effect of fiscal decentralisation on government efficiency [Faguet, 2004, Fisman and Gatti, 2000], although there are some exceptions (e.g., Treisman [2000]).

In order to assess the impact of fiscal decentralisation on efficiency, Barankay and Lockwood [2007] advocate the need to estimate the decentralisation's effect in a model that mimics the production function of government activities using longitudinal datasets. To support their criticism, a model of the education system's production function has been estimated by means of panel data from Swiss cantons during the period of 1982 to 2000. Their empirical results strongly support the concept that decentralisation has a positive impact on efficiency of the education system. Following the same idea, but using a different methodology, Adam et al. [2008] identified the effect of fiscal decentralisation using a "two-stage approach". In the first stage, data envelopment analysis of a panel of 21 OECD countries for the 1970 to 2000 period was used to compute country-specific efficiency indices. In the second stage, country-specific efficiency indices were regressed on an extensive set of alternative fiscal decentralisation measures. Again, their results strongly support the evidence of a positive and significant effect of decentralisation on government efficiency.

The empirical strategy, therefore, is to treat the 1995 change in the regional political institutions and the 1998 tax reform as two exogenous policy variations in order to evaluate their individual and joint effect on the technical efficiency of the regional health care systems. In line with the previous empirical literature, a reduced form relationship is estimated, since we do not have direct evidence of a reduction in rent diversion or lobbing

[8] In the spirit of the *Leviathan hypothesis* [Brennan and Buchanan, 1980] tax competition should reduce local government taxing power, improving voters welfare only if officials are rent-seeking. Otherwise, the "race to the bottom", (reduction of the tax rate) would have a high probability of reducing social welfare due to an undersupply of public goods.

activity. Unlike Barankay and Lockwood [2007] and Adam et al. [2008] the impact of the policy change is evaluated by estimating a frontier production function by both a parametric (stochastic frontier models) and nonparametric approach (data envelopment analysis).

4 The dataset

Data envelopment analysis (DEA) and panel data stochastic frontier models (SFM) will be used to measure the effect of the two policy variations on efficiency of the Italian health care sector using a longitudinal dataset made up of financial and health care data disaggregated at regional level between 1991 and 2005.[9] Each regional government will be treated as a decision making unit that provides health care services on the behavioural assumption that each of them operates in order to maximise the output given the inputs. Five of the twenty Italian regions (the two main islands and three border regions in the north)[10] are not directly comparable with the others because of their higher degree of fiscal and decision-making decentralisation and because their electoral system was not affected by the 1995 reform, therefore these five regions will be excluded from the dataset. As a result, the cross-sectional dimension will be composed of the remaining fifteen regions, that can be grouped into three macro-regions, north, centre, and south according to their geographical position and taking into account the socio-economic divide between southern regions and the rest of the country.[11]

Table 1: Analysis of variance - regressors and dependent variables

Variables		overall		Std. Dev.			No. of obs.	
		mean		*overall*	*between*	*within*	*i*	*t*
Output variable								
life expectancy	*life*	78.79	(years)	1,60	0.61	1.48	15	15
neonatal mortality (one month)	*mort*	12.66	(no. / 10000)	4.66	2.12	4.16	15	15
Inputs variables								
outpatient clinics	*inp*	27.70	(no./100000)	10.31	9.61	4.44	15	15
emergency services	*inp*2	7.30	(no./100000)	6.35	6.50	0.83	15	15
Fiscal decentralisation variables								
dummy = 1 from 1998	*dec*		(dummy)				15	15
Per capita regional own tax rev.	*tax*	372.44	(€)	363.51	114.43	346.22	15	15
Reg. own tax rev./ courrent rev.	*dect*	23.25	(%)	22.12	7.42	20.91	15	15
Electoral variable								
dummy = 1 form 1995	*elect*		(dummy)				15	15
Other environmental variables								
Per capita real GDP	*gdp*	20,975	(€)	5,328	5,169	1,826	15	15
Per capita households health exp.	*hexph*	390.42	(€)	99.18	75.56	66.69	15	15
Dependancy ratio	*dep*	49,29	(%)	3.89	3.22	2.34	15	15

[9] Our dataset is a perfectly balanced panel data and the dimensions of the panel are $N = 15$ and $T = 15$ or $T = 14$ when lags are used as instruments for endogenous variables.

[10] Friuli-Venezia Giulia, Sardegna, Sicilia, Trentino-Alto Adige, Valle d'Aosta.

[11] North: Piemonte, Lombardia, Veneto, Liguria, Emilia Romagna. Centre: Toscana, Marche, Umbria, Lazio, Abruzzo. South: Molise, Campania, Puglia, Basilicata, Calabria.

Output and input variables

The identification of the output of the health system is quite a difficult issue because the effectiveness of the health service should be measured from a number of aspects; for example, the increase in the length and quality of life, equity of access to services etc., which means that just one indicator may not be an appropriate measure of output. The composite indicator elaborated by the World Health Organisation [WHO, 2000] has, however, been criticised on several grounds by Hakkinen and Joumard [2007], and many analyses of the health expenditure effectiveness have used only life expectancy or mortality indices as outcome variables [Afonso and Ammar, 2005, Or, 2000]. In their assessment of efficiency in the health sector across 191 countries Evans et al. [2000] measured the outcome in terms of Disability Adjusted Life Expectancy (DALE), an indicator of healthy life expectancy that differs from the "pure" life expectancy or mortality indices in that it takes into account the quality of life other than its length. Recently, a report by the Italian government [Bellini et al., 2001] aimed at developing a system of indicators for the evaluation of the performance of the health care system in different dimensions. On the basis of the action also taken in this direction by other developed countries, the main conclusion of the report is that an all-inclusive index able to measure the performance of the system alone does not exist and that the most suitable indicators are, at the moment, life expectancy (at birth or at age 75), DALE, and mortality indices (mainly infant and neonatal).

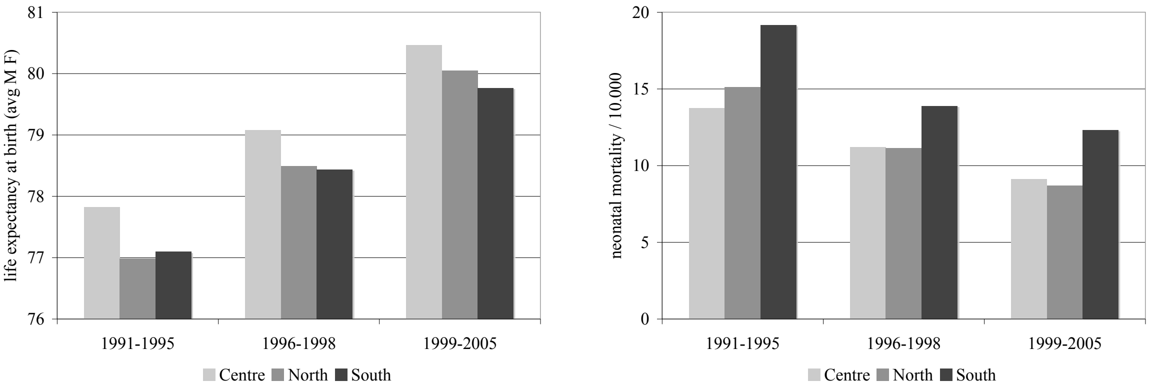
Since DALE disaggregated at regional level did not cover the entire time-series dimension, life expectancy at birth[12] and neonatal mortality[13] have been chosen as output measures. When the production frontier is estimated by a data envelopment analysis, which does not require a particular functional form to be specified, the results are quite robust to the choice of the output measure. Conversely, in the stochastic frontier approach, the functional form of the production function needs to be specified. Further, in the case of life expectancy, the data generating process can be approximated quite well by a simple Cobb-Douglas production function, whereas in the case of neonatal mortality, a more flexible trans-log functional form seems to be required. The problem is that the larger number of parameters necessary in the latter specification of the production function is not compatible with the actual sample size. Therefore, unlike data envelopment analysis, only life expectancy is considered as an output measure in the stochastic frontier approach.

Figure 2 reports, by macro region, average life expectancy and neonatal mortality registered in three different periods: (1) 1991-1995, before the electoral reform, (2) 1996-1998, after the electoral reform, but before the tax reform, (3) 1998-2005, after the tax reform. As we can see, both measures increased in each of the three periods. That is, they exhibit sufficient time variation to be used as dependent variables. This is confirmed by Table 1 in which the reported "within" standard deviations are one year and a half and more than four units per 10,000 newborns. On the other hand, both measures exhibit little "between" variations among regions. In fact, in Table 1 the "between" standard

[12]Life expectancy is the average number of years of life remaining at a given age and is computed separately for men and women. Therefore, male and female life expectancies have been averaged by male and female populations in order to obtain a single value.

[13]Neonatal mortality is the number of neonates, who die during the first month of life, per 10.000 Newborns. In a developed country, is a better measure than infant mortality where the numerator of the ratio is the number of children who die during the first year of life.

deviation is roughly half of the "within" variation in both cases. As explained in detail in Section 6, this aspect may inflate the estimated general level of efficiency in the health care sector, but does not undermine the validity of comparisons across time and space.



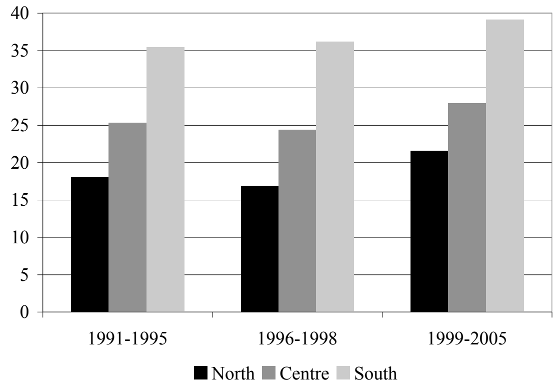
(a) average life expectancy (b) neonatal mortality (one month)

Figure 2: Output variables by macro-region across three period in time: 1991-1995, 1996-1998, 1999-2005. Source ISTAT [2008].

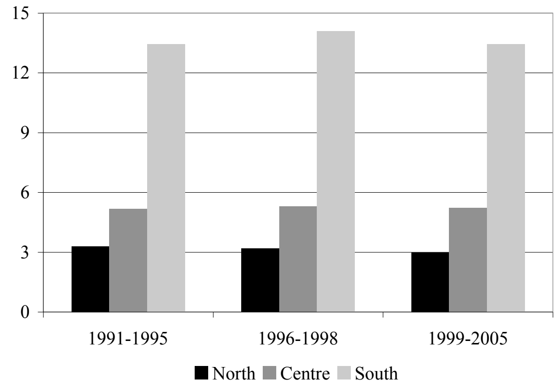
Inputs can be measured in physical terms (no. of doctors, hospital beds, etc.) and/or in financial terms (health care spending). Since either DEA or SFM will be used to estimate technical efficiency, inputs will be considered only in physical terms.[14] With regard to data availability, the number of public outpatient clinics and laboratories per 100,000 inhabitants (public or private structures financed by government funds) has been used as a measure of capital. Then, the number of emergency services carried out per 100,000 inhabitants, has been used as a measure of labour. Table 1 shows that, on average, there are almost 28 outpatient clinics per 100,000 inhabitants and more than seven services per 100,000 inhabitants are carried out on average each year. Moreover, in both cases, we observe a greater "between" variation that reflects a substantial difference in the way regional governments employ resources. Figure 3 shows that southern regions employ more inputs than does the rest of the country. Therefore, different levels of efficiency among regions will be driven by the input side. The smaller variations observed over time, instead, suggest that different levels of efficiency over the years will be driven mainly by the output side.

Finally, inputs can be correlated with the idiosyncratic error term. Therefore, lagged input variables have been used as instrumental variables, and in order to provide overidentification, the instruments will include, separately, either the number of "public" outpatient clinics and laboratories per 100,000 inhabitants or the number of "private" outpatient clinics and laboratories per 100,000 inhabitants that are financed by public funds.

[14]This choice does not allow to expand the evaluation of efficiency also to the financial side of the system because to that end we need to compute allocative efficiency estimating a cost frontier rather than a production frontier, this exercise is left to further extensions due to the higher amount of data required.



(a) number of outpatient clinics and laboratories per 100000 inhabitants



(b) number of emergency services per 100000 inhabitants

Figure 3: Input variables by macro-region across three period in time: 1991-1995, 1996-1998, 1999-2005. Source ISTAT [2008].

Environmental variables

Environmental variables (EV)[15] are variables that influence the output level and efficiency but are out of the control of the producers. They can be subdivided in two main categories. First *policy variables*, that will be used to capture the effect of the two policy variations. Second *non-controllable inputs*, although one can think of this last group of EVs as a classical set of control variables, they are important in accounting for those environmental factors that might affect, and also explain, regional performances together with policy variations.

Figure 1 clearly shows a structural break in the funding system of the health care sector, therefore as a main fiscal decentralisation variable I have decided to use a dummy variable (*dec*) that takes value zero from 1991 to 1997 and value one afterwards which essentially capture the 1998 tax reform. To capture the effect of the electoral policy variation I will use a discrete variable that takes value one starting from 1995. For robustness checks of the measure of fiscal decentralisation two other variables have been defined: (1) the per capita amount of own regional tax revenues (*tax*) in real values; (2) the percentage share of regional own tax with respect to the sum of total current grants and own tax revenues (*dect*). Table 1 shows that on average regional tax revenue is more than 370 euros per capita and accounts for 23% of the total current budget revenue. As expected, most of the variation is registered across time rather than between regions.

Variables used as non-controllable inputs are: the real GDP per capita (*gdp*) to control for the standard of living which provides also a proxy for the level of schooling that was not available at regional level for the first part of the 90s. As reported in Table 1, the average per capita GDP is almost 21,000 euros, and most of the variation is registered between regions rather than across time. In southern regions real income is on average 40% below that of the rest of the country. Then per capita real household health expenditure

[15]Two main references that survey the methodologies to estimate the effect of the environmental variables are Coelli et al. [2005] for DEA models and Kumbhakar and Lovell [2000] for SFM.

(*hexph*), that has been introduced to control for the contribution of the private sector to the health condition of the population. Table 1 reports an average value of 390 euros and its variation is more or less the same either across time or between regions. Similarly to the GDP distribution northern regions register the highest values followed by central and southern regions. And finally the dependency ratio (*dep*), that corresponds to the percentage share of the population over 65 and below 14 with respect to the population between 15 and 64 and accounts for the demand pressure on health services (see Table 1).

An important issue is the possibility that some of these variables can be endogenous. As already discussed in Section 2, the exogeneity of policy variables is ensured by the fact that both reforms have been implemented by central government simultaneously in all regions, i.e. regional governments could not decide independently when to hold elections or when to decentralise part of the health funding system. Therefore, our measures of funding decentralisation mainly capture the effect of the central government policy aimed at reducing the dependence of regions on unconditional grants. As far as non-controllable inputs are concerned, the set of instrumental variables will include the lagged variable of each endogenous variable, one period lagged of resident population over 75, and one period lagged public health expenditure.

5 The empirical model

Regional governments are assumed to produce health care output according to the following production function:

$$y_{it} = f(\mathbf{x}_{it};\beta)g(\mathbf{z}_{it};\gamma)exp(v_{it} - u_{it}) \quad i = 1, 2, ..., N \text{ and } t = 1, 2, ..., T. \qquad (1)$$

where N is the number of regions, T the number of years, y_{it} the output of the health care sector, $\mathbf{x}_{it}$ is a (L × 1) vector of inputs, $\mathbf{z}_{it}$ is a (M × 1) vector of environmental variables (EVs) , β a vector of technology parameters, γ the vector of EVs coefficients. For simplicity, and with little loss of generality, we assume a separability between $f(.)$, which describes the technology of the health care sector, and $g(.)$, which represents the way in which environment affects the output and, consequently, efficiency. The error term has two components - the idiosyncratic error v_{it}, which accounts for the statistical noise in the production function, and the inefficiency error component u_{it}, which is assumend to satisfy the restriction $u_{it} \geqslant 0$. Finally, indices of efficiency e_{it}, which are specific to each region and each time period, can be defined as:

$$e_{it} = exp(-u_{it}) = \frac{y_{it}}{f(\mathbf{x}_{it};\beta)} \times \frac{1}{g(\mathbf{z}_{it};\gamma)} \times \frac{1}{exp(v_{it})} \qquad (2)$$

where e_{it} is a number between 0 and 1 that corresponds to the reciprocal of the Debreu-Farrell measure of technical efficiency [Debreu, 1951, Farrell, 1957]. The closer it is to one, the more efficient the region is.

Depending how $f(.)$ is estimated, it is possible to distinguish between parametric and non-paremetric approaches. With regards to our assumption about the stochastic component of the model (v), it is possible to distinguish between stochastic and deterministic methods. Panel data stochastic frontier models (SFM) allow for statistical noise, but are parametric since they require the specification of $f(.)$. Conversely, data envelopment analysis (DEA) requires no assumption about $f(.)$, but is deterministic, since v is assumed to be equal to zero, hence no form of statistical noise or measurement error can be distinguished from inefficiency. Therefore, the impact of the two policy variations on regional government efficiency has been evaluated using both methodologies, thereby testing the robustness of the results with respect to the assumption behind the two approaches.

Moreover moving $g(\mathbf{z}_{it};\gamma)$ on the left hand side of (2), and assuming that the stochastic component can be separated correctly from the inefficiency error component, we can identify a "gross" index of efficiency $\tilde{e}_{it} = e_{it}g(\mathbf{z}_{it};\gamma)$. This is important, because by comparing regional rankings obtained using the two indices, it will be possible to derive further evidence about the way in which the environment affects the performance of regional governments in the provision of health care services.

Panel data stochastic frontier models

In this framework, the impact of the EVs on regional efficiency can be estimated consistently by specifying the following log-linearised version of the stochastic production function in equation (1):

$$\log y_{it} = \sum_{l=1}^{L} \beta_l \log x_{lit} + \sum_{m=1}^{M} \gamma_m \log z_{mit} + \epsilon_{it} + \alpha_i \tag{3}$$

Where output is measured in terms of life expectancy, the technology of the health care sector is specified by using a *Cobb-Dougals* production function with non-neutral technological change.[16] The unobserved heterogeneity α_i corresponds to the inefficiency error component $(-u_{it})$ averaged across time because we assume fixed effect, and $\epsilon_{it} \sim i.i.d.(0, \sigma_\epsilon^2)$ accounts for the stochastic component of the model (v_{it}).

The key feature of the panel data SFM approach is the association of the "individual effect" in the panel data literature with the "inefficiency error term". How this association is formulated distinguishes the *fixed effect model* (FE), the benchmark model due to the reduced number of assumptions required for consistency, from the *random effect model* (RE).[17]

Given the foregoing, let us consider in more detail the FE SFM first. Owing to the long panel structure of the dataset - which means that the asymptotic properties will be based only on the number of periods - the unobserved heterogeneity across regions (α_i) can be treated parametrically, including a set of regional-specific dummies. The main advantage of doing so is to avoid a distributional assumption, as well as problems of correlation with the other regressors. Consequently least square dummy variables (LSDV) is the simplest consistent estimator (equivalent to within the group estimator). Coefficients' point estimates for the EVs and the input variables are displayed in column (3) of Table 4 where the set of instrumental variables that were described in the previous section is used if the hypothesis of exogeneity for the EVs is rejected. In that case, LSDV estimator is replaced by generalized method of moments estimator (GMM).

Regional dummies α_i can be normalised in order to derive a time-invariant index of "net" technical efficiency $e_i^{SFM} \in [0, 1]$ that provides a relative evaluation of regional efficiency, after taking the effect of the environment into account, comparing each region

[16]This implies the inclusion of a linear trend ad its interaction with the inputs.

[17]Stochastic frontier models have been developed simultaneously by Aigner et al. [1977] and Meeusen and van den Broeck [1977], a complete survey about panel data models is provided by Kumbhakar and Lovell [2000].

with the most efficient one.[18] Given the impossibility of introducing time variations, e_i^{SFM} can be interpreted to be the average level of "net" efficiency attained by each regional government between 1991 and 2005. Although, in the literature concerning SFM, there is a variety of methods to include time variation in the efficiency error component (see, for example, Coelli et al. [2005] and Kumbhakar and Lovell [2000]) in the case of FE SFM, it is not possible to distinguish between technical change and time variation in efficiency because two different trends cannot be identified. Then, the inclusion of years dummies among the regressors is not feasible, since that would generate an incidental parameter problem.

In conclusion, when the assumption of independence between the inefficiency error term and the other regressors, as well as the assumptions about the distributions of the two error components are tenable - assumptions that are not required in case of FE model - it would be possible to consistently estimate an RE SFM. This last kind of model, however, will play only a minor role here as we do not need to identify the effect of time invariant inputs or time invariant environmental variables. Nevertheless, a random effect configuration of the model in (3) has been estimated following the methodology suggested by Battese and Coelli [1995]. Although the results are very similar (compare columns 3 and 4 of Table 4), the fixed-effect configuration is more reliable since the validity of the additional assumptions required for the consistency of the random effect specification has been rejected.[19]

Data envelopment analysis

In the case of DEA, since no assumption are made about the functional form of $f(.)$, the impact of EVs on efficiency has been estimated following a two-stage procedure.[20] In the

[18] As underlined by Schmidt and Sickles [1984] as $T \to \infty$ and N is fixed, like in this case, we can consistently separate the overall intercept from the one-sided individual effect, which provides only the measure of efficiency relative to an absolute standard represented by the most efficient region in the sample that will have $e_i^{SFM} = 1$. Only when also $N \to \infty$ estimates of u_i are fully consistent and can be interpreted also as cardinal measure of efficiency.

[19] Consistency of the MLE used to estimate the RE model hinges on two main assumptions: independence between the inefficiency error term and the inputs, and the correct specification of the distributions of the inefficiency error term and the stochastic error component assumed, respectively, truncated-normal and normal. As proposed by Schmidt and Sickles [1984], these two joint hypotheses could be tested by a *Hausman test* based on the difference between the MLE and the GMM estimator. According to the result of this test, reported at the end of Tables 4, it is possible to reject the null hypothesis of consistency of the MLE but only at 10% significance level. We are at the border of the rejection area and it is not possible to gain a clear understanding about the validity of the two assumptions. Moreover it is important to notice that in case of RE SFM the assumption of exogeneity of EVs comes implicitly by the assumption of independence between the two error component since the RE model developed by Battese and Coelli [1995] includes EVs directly in the specification of the mean of u.

[20] One of the first application of this procedure was that of Timmer [1971] in an attempt to explain interstate variation in technical efficiency in US agriculture. A two-stage approach has been used also by McCarty and Yaisawarng [1993] to investigate efficiency in New Jersey public school districts. Worthington and Dollery [2002] compare different methods to account for the effect of EVs on the efficiency of 73 New South Wales local governments in Australia. Afonso and Aubyn [2006] considered a two-stage approach in relation to the health production process of OECD countries by regressing efficiency scores on EVs like GDP per head, education level, and health behaviour (such as obesity and smoking habits). Recently Adam et al. [2008] have used the same methodology to estimate the effect of decentralisation on the efficiency of the public sector using a panel of 21 OECD countries over the period 1997 to 2000 (this is typical example where the EV is represented by a policy institution).

first stage, linear programming is used to compute a "gross" index of efficiency $\tilde{e}_{it}^{DEA}$ since the EVs are not taken into account. In particular, let ϕ_{it}^{*} be the solution of the following linear program:[21]

$$\max_{\phi,\lambda} \phi_{it} \quad s.t. \;\; \mathbf{x_{it}} \geqslant \mathbf{X_t}\lambda; \;\; \mathbf{y_t}\lambda \geqslant \phi y_{it}; \;\; \lambda \geqslant 0; \;\; \iota'\lambda = 1. \tag{4}$$

Then, $\tilde{e}_{it}^{DEA} = 1/\phi_{it}^{*}$, in order to be a number constrained between 0 and 1.[22] This is again an index of relative efficiency because each region is assessed in relation to the best observed practice in the sample.

Since regional governments, as producers of public goods,[23] have more control of output than of inputs, efficiency is evaluated by the "output approach", i.e. each regional government is considered to be a decision making unit that operates to maximise its health output, given a fixed amount of inputs. To take into account the effect of the technical change, a panel approach has been followed. This means that the constrained maximisation in (4) has been solved $N \times T$ times, so that each input-output combination is assessed only in relation to the production frontier related to a specific year. In this way, the effect due to the technical change that shifts the production frontier across time is neutralised.

Subsequently, in order to assess the impact of EVs on efficiency, in the second stage the fixed effect panel data model in (5) is estimated, where $\tilde{e}_{it}^{DEA}$ is regressed upon the EVs.

$$\tilde{e}_{it}^{DEA} = h(\mathbf{z}_{it}; \gamma; \alpha_i) + \epsilon_{it} \tag{5}$$

Where $\epsilon_{it} \sim i.i.d.(0, \sigma_\epsilon^2)$. Owing to the long panel structure of the dataset, the unobserved heterogeneity across regions (α_i) can be treated parametrically, including a set of regional-specific dummies. Assuming linearity ($h(\mathbf{z}_{it}; \gamma; \alpha_i) = \mathbf{z}_{it}'\gamma + \alpha_i$), LSDV is the simplest consistent estimator. On the other hand, this assumption may not be appropriate as the dependent variable can vary only between zero and one. A possible solution is to assume that $h(\mathbf{z}_{it}; \gamma; \alpha_i) = \Phi(\mathbf{z}_{it}; \gamma; \alpha_i)$ where $\Phi(.)$ is the standard normal cumulative distribution function so that the fitted values of the efficiency scores will neither exceed 1 nor be less than 0. Under the assumption of non-linearity, the model can be estimated by a *pooled Bernoulli quasi-MLE* (QMLE) as proposed by Papke and Wooldridge [2008].[24] Coefficients' point estimates for the EVs are displayed in column (1) and (2) of Table 4, for the linear and non-linear case respectively. The results are very similar and, in the

[21] In (4) $\mathbf{x_{it}}$ is a *(L×1)* vector of input of region i at time t, $\mathbf{X_t}$ is a *(L×N)* matrix of inputs of all regions, $\mathbf{y_t}$ is a *(1×N)* vector of outputs of all regions, λ is a *(N×1)* vector of optimal weights attached to the peers of regions i; ι is a *(N×1)* vector of ones, the last constraint is important for imposing variable returns to scale.

[22] A complete survey about DEA is provided by Ali and Seiford [1993].

[23] Here public goods refers also to "rival" and/or "excludable" goods like health care that have a strong social impact.

[24] Most of the empirical works (for example, Goudriaan and de Groot [1991], Bjurek et al. [1992], McCarty and Yaisawarng [1993], Lovell et al. [1993], Borger et al. [1994], Vitalianno [1998], and more recently Afonso and Aubyn [2006]) that use a two-stage approach usually account for the fractional nature of the depended variable using a Tobit model in the second-stage regression (one-limit or two-limits). The only case similar to Bernoulli quasi-MLE has been found in Worthington [1999], who uses a second-stage logistic model. Essentially, as suggested by Papke and Wooldridge [2008], the possible choice of a two-limit Tobit model for the second-stage regression is not suitable in this contest because, although our response variable is bounded from below by zero, there are no observations at zero.

case of endogeneity, the set of instrumental variables discussed in the previous section has been used. For computational reasons, a two-stage least square estimator will be used in two steps in the case of the non linear model. Consequently, standard errors need to be corrected (see Papke and Wooldridge [2008]). In contrast, the linear model is estimated by GMM in place of LSDV.

Finally, as proved in the appendix, regional dummies can be normalised in order to derive a "net" index of technical efficiency e_i^{DEA}, a number between 0 and 1 that provides a relative evaluation of regional efficiency after taking into account the effect of the environment. Since we assume a fixed effect and the inclusion of time dummies would generate an incidental parameter problem, e_i^{DEA} is time invariant and can be interpreted as the average level of "net" efficiency that is attained by each regional government between 1991 and 2005. The same comments that we made in relation to e_i^{SFM} are valid here.

Comparison across different measures of efficiency

Regions' rankings obtained using e_i^{DEA} and e_i^{SFM} can be compared in order to evaluate how results might be affected by the the specification of $f(.)$ in the case of SFM, and by the omission of statistical noise in the case of DEA. To provide further evidence in this sense the FE SFM in (3) has been estimated without EVs so that normalised regional dummies can be used as new "gross" index of technical efficiency $\tilde{e}_i^{SFM} \in [0, 1]$ comparable, in terms of regions' rankings, with $\tilde{e}_{it}^{DEA}$ derived by DEA where no assumption are made about the shape of $f(.)$.[25]

Moreover, comparing regions' rankings within each model, between index typologies (between $\tilde{e}_{it}^{DEA}$ and $\tilde{e}_i^{DEA}$, or between e_i^{SFM} and $\tilde{e}_i^{SFM0}$), provides some evidence of how the environment affects efficiency of regional governments. A substantial divergence in the order of the regions means that the environment affects their performance differently. Divergence in regions' rankings would be evidence that some regions, those who lose positions in terms of "net" efficiency, are characterised by a better environment than those who gain positions in "net" efficiency.

Table 2: Relation between efficiency indices.

	Gross index	Net index
DEA	$\tilde{e}_{it}^{DEA}$	e_i^{DEA}
SFM FE model	$\tilde{e}_i^{SFM}$	e_i^{SFM}

Note: only $\tilde{e}_{it}^{DEA}$ is time-variant, therefore analysis of technical efficiency across time can be done only in case of the semi-parametric approach. (see Figure 4).

In the end, as reported in Table 2, four types of efficiency indices can be used to rank regional governments. The "gross index" is computed for each model without controlling for the environment. Instead, the "net index" is computed once the environment's effect has been evaluated by introducing EVs to the model. It is important to stress that all indices provide only a relative evaluation of efficiency comparing each region with the best

[25]Coefficients' point estimates for this second version of the Fixed Effect SFM are displayed in Table 5, where the set of instrumental variables discussed in Section 4 has been used to take into account the endogeneity of inputs, and the model has been estimated by GMM, instead of the LSDV estimator.

practice standard represented by the most efficient region. Therefore the only meaningful comparison is among regions' rankings reported in Table 3.

6 Analysis of the results

As reported in Table 4, 1998 tax reform exhibits the expected positive effect on government efficiency with both approaches, but coefficients' estimates are statistically different from zero (at a 1% significance level) only in the case of the stochastic frontier models. The 1995 electoral reform exhibits a stronger positive impact on government efficiency as its coefficients' estimates have a positive sign and are statistically different from zero at a 1% significance level in all models but the RE SFM. Moreover, the coefficients of the two policy variations are always jointly statistically different from zero at a 1% significance level. Finally, results obtained by DEA are very robust to the choice of the output variable as reported in Table 6 where the health care output is measured in terms of neonatal mortality.[26]

The small magnitude of the coefficients in Table 4 is quite misleading because it is a result of the high absolute level of efficiency reported in the health care sector, that in turn is mainly a consequence of the small variation (especially between the regions) registered in life expectancy at birth employed to measure the output of the sector. In fact, the impact of the two policy variations equal to 0.02% and 0.43%, respectively for the 1998 tax reform and the 1995 ballot (see column (1) of Table 4), is much greater than it might appear considering that the range of variations of DEA efficiency scores, reported in Figure 4 (a), is between 1 and 0.98 which corresponds only to 2% of the entire range.

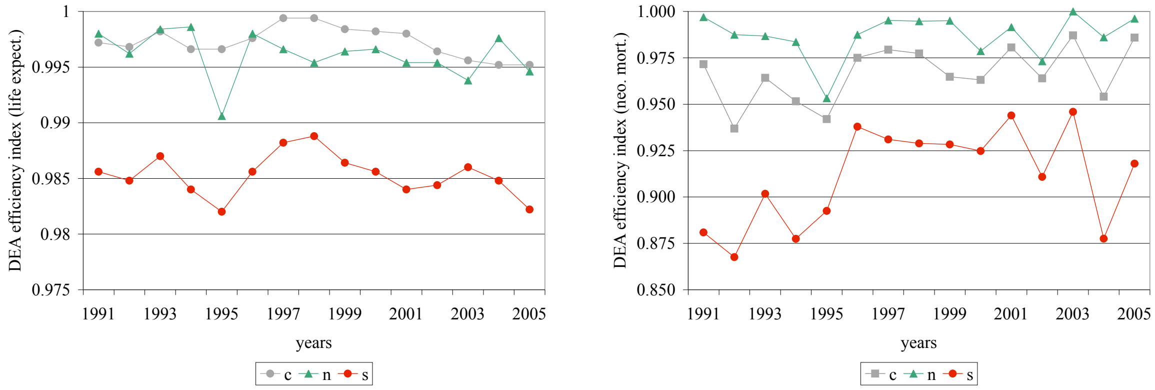
Similarly, in case of SFM, the partial effect reported in our estimates, according to which life expectancy (and also efficiency) increased by 0.40% after the 1995 ballot and by 0.30% after the introduction of IRAP (see column (3) of Table 4) is not so small considering that life expectancy exhibits an overall standard deviation equal to one year and six moths around a mean of 79 years.[27]

Foregoing remarks are confirmed by the fact that coefficients exhibit a bigger magnitude in Table 6 where health care output is measured in terms of neonatal mortality, that showed more variability among regions (see Table 1).

Figure 4 plots the average gross DEA efficiency scores by macro-regions (on the left the output is measured in life expectancy, on the right in neonatal mortality). As noticed above, in general, the health care sector appears to be very efficient, since indices are very close to one. However, this would be an incorrect conclusion, since this result is driven mainly by the fact that both output measures exhibit small variations among regions. In fact, in the case of neonatal mortality, where we register a slightly more intense "between" variation (see Table 1), the health care sector appears to be less efficient. However, this is not a problem because our main interest is in using these indices of efficiency to compare values by region and time and not to assess efficiency in absolute terms.

[26]As explained in Section 4, in the case of SFM only life expectancy has been used as a dependent variable because the heavy parametrization of the trans-log production function required in the case of neonatal mortality is not compatible with the sample size.

[27]It is important to stress that we have found no significant difference in the effect of the policy variables across regions by grouping them into the three geographical macro regions (north, centre, south). This evidence of uniform effect, however, might be driven by the small sample size.



(a) output in terms of life expectancy (b) output in terms of neonatal mortality

Figure 4: DEA "gross" technical efficiency indices ($\tilde{e}_{it}^{DEA}$), average across macro-regions (n = notrh, c = centre, s = south), year 1991-2005.

In general, without taking into account the effect of the environment, and independently of the output measure a clear increase in inefficiency is observed after 1995, but no particular change in the efficiency path is registered after 1998. Moreover, in terms of "gross" indices of efficiency, southern regions[28] appear to be less efficient than the rest of the country as reported also in Table 3. On the other hand, especially in case of SFM, the change observed in regions' ranking shows that the environment plays a role in the evaluation of the relative performance.

In order to viualize this, let us consider Table 3 where the *Spearman index* between $\tilde{e}_i^{SFA}$ and e_i^{SFA} equal to 0.56, much lower than the 0.825 obtained by comparing the gross and net indices in the case of DEA. Therefore we can also conclude that the SFM attach a slightly different effect to the environment than the two-stage approach.

Comparison of regions' rankings across different models provides a further external validity test for the results: the *Spearman index* between $\tilde{e}_i^{SFA}$ and $\sum_{t=1}^{T} \tilde{e}_i^{DEA}/T$ is equal to 0.87 and is statistically significant at 1%, net indices exhibit less similarity highlighted by a *Spearman index* between e_i^{SFA} and e_i^{DEA} equal to 0.67 but it is still positive and statistically significant at 1%.

This last evidence as well as the stability of the results across different models corroborate the Cobb-Doublas choice for the specification of the production function, and at the same time show that most of the deviation from the frontier is due to inefficiency rather than to statistical noise.

7 Conclusions

The contributions of this paper are twofold. Firstly, it provides an empirical analysis of the impact that the 1995 renewal of regional political institutions and the 1998 tax reform might have had on the efficiency of Italian regional governments. This is the first

[28]Molise, Campania, Puglia, Basilicata, Calabria.

Table 3: Regional health system rankings according to average technical efficiency indices, year 1991 and 2005.

Data Envelopment Analysis (DEA)		Stochastic Frontier Model (SFM)	
(1) $\sum_{t=1}^{T}\tilde{e}_i^{DEA}/T$ = DEA index of technical efficiency, average across years)	(2) e_i^{DEA} = DEA net index of technical efficiency (non-linear second stage model)	(3) $\tilde{e}_i^{FE}$ = Fixed Effect Stochastic Frontier Model index of technical efficiency	(4) e_i^{FE} = Fixed Effect Stochastic Frontier Model net index of technical efficiency
(c) Marche	(c) Marche	(c) Marche	(c) Marche
(n) Veneto	(c) Umbria	(c) Umbria	(c) Toscana
(n) Lombardia	(n) Veneto	(n) Emilia Romagna	(c) Abruzzo
(c) Umbria	(c) Lazio	(n) Veneto	(c) Umbria
(n) Emilia Romagna	(c)Toscana	(c) Toscana	(n) Veneto
(c) Lazio	(n) Emilia Romagna	(c) Abruzzo	(s) Calabria
(c) Toscana	(c) Abruzzo	(n) Lombardia	(s) Puglia
(c) Abruzzo	(s) Molise	(s) Puglia	(s) Basilicata
(n) Piemonte	(n) Lombardia	(c) Lazio	(s) Molise
(s) Molise	(s) Puglia	(n) Piemonte	(n) Emilia Romagna
(n) Liguria	(s) Calabria	(n) Liguria	(c) Lazio
(s) Puglia	(n) Liguria	(s) Molise	(n) Lombardia
(s) Basilicata	(s) Basilicata	(s) Campania	(n) Piemonte
(s) Calabria	(n) Piemonte	(s) Calabria	(n) Liguria
(s) Campania	(s) Campania	(s) Basilicata	(s) Campania

n = north, c = centre, s = south.

Spearman index $\sum_{t=1}^{T}\tilde{e}_i^{DEA}/T$ vs $e_i^{DEA} = 0.8250$ ($prob > |t| = 0.0000$)

Spearman index $\tilde{e}_i^{FE}$ vs $e_i^{FE} = 0.56$ ($prob > |t| = 0.0000$)

Spearman index $\sum_{t=1}^{T}\tilde{e}_i^{DEA}/T$ vs $\tilde{e}_i^{FE} = 0.87$ ($prob > |t| = 0.0000$)

Spearman index e_i^{DEA} vs $e_i^{FE} = 0.67$ ($prob > |t| = 0.0000$)

time that this issue has been addressed using Data Envelopment Analysis and Stochastic Frontier Models.[29]

As discussed in the previous section it seems that only the 1995 political renewal unambiguously fostered electoral accountability in such a way to stimulate government efficiency. Whereas 1998 tax reform exhibited a weak and ambiguous positive impact on efficiency suggesting that the little opportunity regional governments had to set regional tax rates (see Section 2) might have not generated neither yardstick competition nor tax competition required to stimulate electoral accountability. In further empirical analysis, therefore, it would be interesting to evaluate the impact that 1995 political renewal might have had on the level of corruption as well as the impact that 1998 reform might have had on yardstick and tax competition among regional governments.

Secondly, the paper provides an analysis of technical efficiency in the health care sector between 1991 and 2005. In general, without taking into accout the effect of the

[29]Recently Mapelli [2007] provides a detailed analysis of the Italian health care system assessing regional performances by a complex system of indicators between 1995 and 2005.

environment, southern regions are less efficient than the rest of the country. Moreover, by comparing regional rankings that are obtained using "gross indices" of efficiency with those obtained considering "net indices" of efficiency - by which we evaluate regional performance controlling for the effect of environmental variables - we observe that some regions rise from the bottom of the table to the top, whereas others do the opposite (see Table 3).

One explanation for this result is that the poor performance of regions for which placement improves when we control for the effect of the environment may be due to circumstances that the regional governments are unable to control. In the case of those regions that continue to remain at the bottom of the table, there is evidence that poor performance is more directly a consequence of low efficiency in the provision of the health care services. Therefore, a key strategy for improving the performance of those regions that substantially raised their performance rankings could be to first address problems, such as the low levels of income, and then the government's inefficient management of the resources (e.g., Puglia). Conversely, with regard to those regions that continue to remain at the bottom of the table when controlling for the environment effect (e.g., Campania), the poor performance is a symptom of a severe problem in the management of resources. In such cases, the poor performance of the government should be the first point on the agenda of reforms necessary to improve efficiency (see Table 3).

Many improvements and extensions are still possible. For example, in order to strengthen the validity of the results, it would be advisable to estimate a cost frontier model that, unlike the production frontier, permits multiple outputs. Moreover, a cost frontier model will also provide a measure of "economic efficiency", thereby expanding the evaluation of efficiency to include the financial aspects of the system. On the other hand, with respect to production frontier models, the main limitation of cost frontier models is in the higher quality, and greater quantity of data required. Therefore a bigger sample size is the prerequisite condition for a more precise analysis, that can be achieved only by using micro-data at the level of local health authorities or hospitals.

Finally, a major pitfall of the panel data stochastic frontier model approach is that both RE and FE models force any time invariant cross unit heterogeneity into the same term used to capture the inefficiency. Therefore, there is a risk of picking up "unobserved heterogeneity" in addition to, or even instead of, inefficiency. A substantial extension would be necessary in order to tackle this issue. For example, one of the solutions suggested by Greene [2005] is a modified version of the traditional fixed effect stochastic fronter model, called the "true fix effect" model. However, this is an extreme solution that generates, in some senses, a diametrically-opposed, new problem since no time invariant factors in this model will affect the inefficiency error component at all.

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Appendix

In order to show how, in case of panel data, the second stage can be used to derived a "net" index of efficiency we can start from the deterministic version of the frontier model in (1) in case of cross-section:

$$y_i = f(\mathbf{x}_i; \beta)g(\mathbf{z}_i; \gamma)exp(-\psi_i) \quad i = 1, 2, ..., N. \tag{6}$$

where $\mathbf{z}_i$ is a vector of environmental variables, γ is the vector of EVs coefficients, and $exp(-\psi_i) \simeq e_i^{DEA}$. The second-stage regression can be derived by rearranging (6) in (7):

$$exp(-\psi_i) = \frac{y_i}{f(\mathbf{x}_i; \beta)} \frac{1}{g(\mathbf{z}_i; \gamma)} \tag{7}$$

where $\frac{y_i}{f(\mathbf{x}_i; \beta)} \simeq \tilde{e}_i^{DEA}$, therefore (7) becomes:

$$e_i^{DEA} \simeq \tilde{e}_i^{DEA} \frac{1}{g(\mathbf{z}_i; \gamma)} \tag{8}$$

Finally, since e_i^{DEA} is not observed and $\tilde{e}_i^{DEA}$ comes from the first stage DEA, rearranging equation (8) we obtain the second-stage general empirical model in the case of the cross-section:

$$\tilde{e}_i^{DEA} = g(\mathbf{z}_i; \gamma)e_i^{DEA} + \epsilon_i \tag{9}$$

where ϵ_i is a zero mean idiosyncratic error term. The linear version of the second-stage empirical model in (9) is:

$$\tilde{e}_i^{DEA} = \mathbf{z}_i'\gamma + \alpha_i + \epsilon_i \tag{10}$$

Since $\alpha_i \simeq e_i^{DEA}$ is not observed it will form a composite error term with ϵ_i:

$$\xi_i = u_i + \epsilon_i \tag{11}$$

and the model in (10) becomes:

$$\tilde{e}_i^{DEA} = \mathbf{z}_i'\gamma + \xi_i \tag{12}$$

as a result, in (12), $E[\mathbf{z}_i|\xi_i] \neq 0 \ \forall i$ unless efficiency will not be influenced by the environment, something that Ray [1988] did not notice in the first specification of the second stage regression in case of DEA. If we have access to panel data (like in this case), one way to deal with the endogeneity of EVs in (12) would be the specification of a Fixed Effect model where point estimates of the individual dummies can be used to derive e_i^{DEA}. Under this assumption (12) becomes:

$$\tilde{e}_{it}^{DEA} = \mathbf{z}_{it}'\gamma + \alpha_i + \epsilon_{it} \quad i = 1, 2, ..., N \ and \ t = 1, 2, ..., T. \tag{13}$$

and α_i can be normalised in the following way in order to constrain e_i^{DEA} between 0 and 1.

$$e_i^{DEA} = exp[\alpha_i - max(\alpha_i)] \tag{14}$$

Table 4: Environmental variables' point estimates (output = life expectancy at birth).

	DEA second stage models		Stochastic frontier models	
	(1)	(2)	(3)	(4)
MODEL	Linear	Non-linear (AvgMargEff)[1]	FE SFM	RE SFM
ESTIMATOR	GMM	QMLE	GMM	MLE
Dip. Variable	$\tilde{e}^{DEA}$	$\tilde{e}^{DEA}$	log of Life expect.	log of Life expect.
fiscal decentralisation dummy (dec_{t-1})	0.0223	0.0199	0.2891**	0.6424**
	(0.0816)	(0.0956)	(0.0850)	(0.3241)
electoral dummy ($elect_{t-1}$)	0.4280**	0.5749**	0.3855**	0.3595
	(0.1003)	(0.0839)	(0.0798)	(0.2763)
H_0: (dec elect) = 0, $\chi^2(2)$	19.45**	47.97**	25.39**	24.78**
σ^2_{v-u}				0.0028**
				(0.0004)
σ^2_u / σ^2_{v-u}				54.7487**
				(6.2411)
gdp_{it} (log per capita real gdp)	0.8668	0.5576	1.2424	1.3895*
	(1.2004)	(1.0993)	(1.2437)	(0.7590)
dep_{it} (dependancy ratio)	-0.0525	-0.0767	0.0956	0.1240**
	(0.0537)	(0.0605)	(0.0723)	(0.0241)
$hexph_{it}$ (log housholds per capita real health expenditure)	-0.8531	-0.8655^*	0.1438	0.7850
	(0.4514)	(0.4169)	(0.2953)	(0.7190)
$rgdp_{it}$ residuals from the reduced form of gdp		-2.4091		
		(2.0107)		
$rdep_{it}$ residuals from the reduced form of dep		0.1576*		
		(0.0698)		
$rhexph_{it}$ residuals from the reduced form of $hexph$		1.7401*		
		(0.7571)		
H_0: (rgdp, rdep, rhexph) = 0 $\Longrightarrow$ H_0: (gdp, dep, hexph) are exogenous, $\chi^2(3)$		11.30**		
Robust Hausman test, H_0: exogeneity [p-val of $\chi^2(.)$]	[0.0457]		[0.0565]	
Hansen J stat. $\chi^2(.)$, H_0: valid instruments. [p-val of $\chi^2(.)$]	[0.3404]		[0.1695]	
Anderson canon.corr. LR stat., H_0: weak instr. [p-val of $\chi^2(.)$]	[0.0000]		[0.0057]	
Pagan Hall heterosk. test, H_0: homosk. [p-val of $\chi^2(.)$]	[0.0133]		[0.8981]	
Sceond Hausman test, H_0: RE model is consistent [p-val of $\chi^2(.)$]			[0.0893]	
Regional dummies	Yes	Yes	Yes	No
No. of observations ($N = 15$, $T = 14$)	210	210	210	210

a) Robust standard errors in brackets () * significant at 5%; ** significant at 1%.

b) Point estimates are in percentage values, and standard errors are × 100.

c) In case of the non-linear model in column (2) the null of exogeneity for *gdp*, *dep*, and *hexph* is tested using a joint *likelihood ratio* test on the significance of the residuals *rgdp*, *rdep*, and *rhexph* form the the reduced forms of each endogenous variable.

d) In case of the linear models in columns (1) and (3) the null of exogeneity for *gdp*, *dep*, and *hexph* is tested using a robust *Hausman test*, the *Hansen J statistics* is used to test the null of exogeneity for the instrumental variables, and the *Anderson canonical correlation* provides a test for the correlation between instruments and endogenous variables. Finally, the *Pagan-Hall test* rejects the null of homoscedastic variance only for the model in column (1), which justifies the use of robust standard errors.

e) In case of RE SFM the ratio $\sigma^2_u/\sigma^2_{v-u}$ reports how much of the variance of the composite error is generated by the inefficiency error component. It corresponds to 55% of the whole variance and is statistically significant at 1%. If it were not statistically different from zero, the efficiency analysis would not have been meaningful.

Note: 1. In column (2) coefficients estimates are reported in terms of average partial effect.

Table 5: Production function without environmental variables, point estimates (output = life expectancy at birth).

MODEL	Fixed Effect
ESTIMATOR	GMM
Dip. Variable	log of *life expectancy*
linear trend (*year*)	0.3906 **
	(0.0225)
non-neutral technological trend ($year * inp_{it}$)	0.0003
	(0.0010)
non-neutral technological trend ($year * inp2_{it}$)	-0.0041**
	(0.0012)
no. of outpatient clinics and laboratories / 100000 inhabitants (inp_{it})	0.0197
	(0.0124)
no. of emergency services / 100000 inhabitants ($inp2_{it}$)	0.1765
	(0.1427)
H_0: $(inp, inp3) = 0$, $\chi^2(2)$	7.81**
H_0: $(inp + inp3) = 1$, $\chi^2(1)$	5.3e+05**
H_0: $(yearinp, yearinp3) = 0$, $\chi^2(2)$	22.84**
Robust Hausman test, H_0: exogeneity [p-val of $\chi^2(4)$]	[0.0006]
Hansen J stat. $\chi^2(.)$, H_0: valid instruments. [p-val of $\chi^2(2)$]	[0.4075]
Anderson canon.corr. LR stat., H_0: weak instr. [p-val of $\chi^2(3)$]	[0.0313]
Pagan Hall heterosk. test, H_0: homosk. [p-val of $\chi^2(28)$]	[0.3573]
Regional dummies	Yes
No. of bservations ($N = 15$, $T = 14$)	210

a) Robust standard errors in brackets (), * significant at 5%; ** significant at 1%

b) Point estimates are in percentage values, and standard errors are × 100.

c) Inputs are in levels and not in log form since are ratios.

d) The model production function exhibits decreasing return to scale since we can reject the null hypothesis that the coefficients of the two inputs are equal to one. Then parameters of the two inputs are jointly statistically different from zero at 1% significance level, as well as those related to the non-neutral technological trend.

e) The small magnitude of the coefficients is mainly driven by the fact that the output is measured in terms of life expectancy. In fact, as reported in Table 1, the overall standard deviation, equal to one year and six months, is much smaller than its mean, equal to 79 years. Therefore it makes sense, according to our estimates, that if we increased the outpatient clinic ratio by one, for example, life expectancy would have increased by 0.02% other things being equal.

f) The *Pagan-Hall* test does not reject the null of homoscedasticity. Then according to the "robust" version of the *Hausman test*, we can reject the null of exogeneity for the input variables at 1%, the *Hansen J statistics* do not reject the null of valid instruments, which means that our instrumental variables are not correlated with the error term, and finally according to the *Anderson canonical correlation* instruments are instead correlated with the input variables.

Table 6: Environmental variables' point estimates (output = neonatal mortality index).

	DEA second stage models	
	(1)	(2)
MODEL	Linear	Non-linear (AvgMargEff)[1]
ESTIMATOR	GMM	QMLE
Dip. Variable	$\tilde{e}^{DEA}$	$\tilde{e}^{DEA}$
fiscal decentralisation dummy (dec_{t-1})	0.6001	0.3150
	(0.8700)	(0.8884)
electoral dummy ($elect_{t-1}$)	4.9491**	5.2908**
	(0.9566)	(0.6701)
H_0: (dec elect) = 0, $\chi^2(2)$	23.53**	43.08**
gdp_{it} (log per capita real gdp)	-20.4691	-19.0104
	(11.6693)	(10.2153)
dep_{it} (dependancy ratio)	-0.0509	-0.0391
	(0.2928)	(0.2915)
$hexph_{it}$ (log housholds per capita real health expenditure)	-6.4280	-5.7251
	(3.3513)	(2.9311)
$rgdp_{it}$ residuals from the reduced form of gdp		-21.2046
		(21.2890)
$rdep_{it}$ residuals from the reduced form of dep		1.8724
		(1.0022)
$rhexph_{it}$ residuals from the reduced form of $hexph$		-8.3128
		(8.8588)
H_0: (rgdp, rdep, rhexph) = 0 $\Longrightarrow$ H_0: (gdp, dep, hexph) are exogenous, $\chi^2(3)$		4.94
Robust Hausman test, H_0: exogeneity [p-val of $\chi^2(.)$]	[0.2820]	
Hansen J stat. $\chi^2(.)$, H_0: valid instruments. [p-val of $\chi^2(.)$]	[0.3103]	
Anderson canon.corr. LR stat., H_0: weak instr. [p-val of $\chi^2(.)$]	[0.0000]	
Pagan Hall heterosk. test, H_0: homosk. [p-val of $\chi^2(.)$]	[0.0019]	
Regional dummies	Yes	Yes
No. of observations ($N = 15$, $T = 14$)	210	210

a) Robust standard errors in brackets () * significant at 5%; ** significant at 1%.

b) Point estimates are in percentage values, and standard errors are × 100.

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ieb@ub.edu
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