HOSPITAL CARE REIMBURSEMENT MECHANISMS AND THE ADOPTION OF MEDICAL TECHNOLOGY IN THE ITALIAN NHS

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PRELIMINARY DRAFT

Abstract.

Current reimbursement schemes imply different incentives for health care providers, among which there are the ones related to the adoption of technology. Several empirical studies have investigated the links between the pattern of medical technology adoption, particularly medical equipment, and a few determinant factors, among which reimbursement mechanisms. Most of these studies, however, focus on single and specific medical equipment and, therefore, their analysis is inherently limited to represent the characteristics of the reimbursement mechanism for the specific services connected with the use of a given technology, with respect to other services. In this paper, we aim at enlarging the scope of analysis so as to consider the impact of the general features of reimbursement mechanisms on the adoption of medical technology. Our analysis is focused on hospital care in Italy. The DRG mechanism was introduced in the early nineties, while, at the same time, regional governments were recognized extended autonomy in the implementation of the payment mechanism (determination of rates, differentiation of the reimbursement system for different providers, etc.). Moreover, these reforms were implemented in a situation characterized by relevant differences across regions, in terms of technological endowments. Our analysis will focus on the change in the medical equipment of Italian hospitals in the period 1997-2007. The data are available for the overall hospital sector, at a regional level (there are 20 regions in Italy). We build up and indicator for measuring the regional endowment of medical equipment, based on a weighted sum of the number of equipment, where the weights are represented by a vector of normalized prices. The main objective of the analysis is to check how the differences across the regional reimbursement mechanisms, above all in terms of how extended is the use of the DRG system in the coverage of the overall financing of hospital care, impact on the change in the equipment endowment, as measured by our indicator.

Keywords: hospital care, medical equipment, prospective payment systems, technology adoption

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1. INTRODUCTION

Current reimbursement schemes imply different incentives for health care organizations, in terms of the different aspects that can be considered as relevant for the evaluation of their activity. Among the most significant incentives, there are the ones related to the adoption of technology, which represents one of the major drivers of costs and an increasingly important input in the production of health. Several empirical studies have investigated the links between the pattern of medical technology adoption, particularly medical equipment, and a few determinant factors, among which reimbursement mechanisms (Bokhari, 2009; Finkelstein, 2005; Baker and Phibbs, 2002). Most of these studies, however, focus on single and specific medical equipment and, therefore, as far as the analysis of the impact of reimbursement mechanisms is concerned, they are unable to compare different mechanisms (e.g. cost per case vs. fee for service) . Their analysis is inherently limited to represent the characteristics of the reimbursement mechanism, for the specific services connected with the use of a given technology, with respect to other services [Pita Barros and Martinez-Giralt (2010)].

In this paper, we aim at enlarging the scope of analysis so as to consider the impact of the general features of reimbursement mechanisms on the adoption of medical technology. Our analysis is focused on hospital care in Italy. The DRG mechanism was introduced in the early nineties, while, at the same time, regional governments were recognized extended autonomy in the implementation of the payment mechanism (determination of rates, differentiation of the reimbursement system for different providers, etc.). Moreover, these reforms were implemented in a situation characterized by relevant differences across regions, in terms of technological endowments. Our analysis will focus on the change in the stock of medical equipment of Italian hospitals in the period 1997-2007. The data are available for the overall hospital sector, at a regional level (there are 20 regions in Italy). We build up and indicator for measuring the regional endowment of medical equipment, based on a weighted sum of the number of different pieces of equipment, where the weights are represented by a vector of normalized prices.

The main objective of the analysis is to check how the differences across the regional reimbursement mechanisms, above all in terms of how extended is the use of the DRG system in the coverage of the overall financing of hospital care, impact on the change in the equipment endowment, as measured by our indicator. Control for variables related to the demand and the supply of hospital services our empirical results suggest that the per case payment system provides incentives to constrain technology adoption.

The paper is organised as follows: section 2 reviews the main findings of the literature, section 3 briefly presents the Italian institutional framework, section 4 describes our data set and develops the empirical analysis and section 5 offers some concluding remarks.

2. A BRIEF OVERVIEW OF THE LITERATURE

Several studies show that medical technology diffusion is one of the most relevant drivers of the increase of public expenditures on health (Smith et al., 2009). The OECD (2005) lists the characteristics of medical technological change capable to have economic consequences: whether the new technology substitutes for old or is add-on to existing one; whether the new technology causes average cost reduction, quality improvement or reduction of risk to patients. First of all, it seems important to precisely define the term "medical technology". This is a difficult task whose outcome depends on the aim of the researcher. A broad definition of medical technology is frequent in studies on non-price competition that refer to both old processes and newly developed devices. Differently the stream of research known as "medical arms race" focus only on newly developed, expensive devices and processes (Spetz and Maiuro, 2004). On this line of reasoning, whereas some works investigated the factors affecting the rate of diffusion of new medical technologies (Cappellaro et al., 2011), we consider as medical technology adoption the purchases of new medical equipment by Italian hospitals.

As for the explanation of the process of adoption of medical technology, the results of the empirical literature connect health care expenditure and technology diffusion, considering several factors such as the degree of

substitutability/complementarity between old and new technologies, the level of effort reduction and output improvement of medical innovation, the role of the costs of technological adoption in accordance with treatment expansion and substitution, the characteristics of the health care system, its financing and regulation (Pita Barros and Martinez-Giralt, 2010). One of those factors that have not received the deserved attention yet by the relevant literature is the role of the different reimbursement systems on the incentive of health care providers to adopt new technologies. Looking first at theoretical papers, Goddeeris (1984) and Baumgardner (1991) studied the link between technology adoption and health insurance market, whereas Selder (2005) analyses the connection between technology diffusion and reimbursement systems in a world with ex-post moral hazard. Miraldo (2007) investigates the impact of different payment systems on the adoption of endogenously provided new technologies by considering a feed-back effect from health care sector into R&D sector. Levaggi and Moretto (2008) show that the investment in new technology is best stimulated within a long-term contract where the number of treatments reimbursed depends on the level of investment made when the technology is new. Also some empirical studies analysed the link between reimbursement systems and technology adoption. For instance, Romeo et al. (1984) and Hirth et al. (2000) on US hospitals and Ikegami (1988) on Japanese hospitals find that low prospective payment rates bear a negative impact on the adoption of technologies, particularly cost-increasing ones, though the extent of this varies from case to case. Also, Bryce and Cline (1998) illustrate positive association between the degree of competition in the health care market and the propensity to adopt new technologies.

Other works have shown that the changes in technology diffusion across countries can be explained by the different regulatory policies and payment systems to providers (McClellan and Kessler, 1999; Burke et al., 2007). The role of remuneration systems has become more important since the adoption of a Diagnosis-Related Groups (DRGs) system. Empirical results show that fixed global-budget schemes do not foster technology adoption (Slade and Anderson, 2001), whereas DRG based systems seem to lead hospitals to choose innovative technologies (Cappellaro et al, 2011). In fact, budgetary constraints push decision

makers to choose between technologies not necessarily leading to most effective or cost-effective ones. The lack of detailed information on the effectiveness and costs of new medical services is seldom available to decision makers (OECD, 2005). This is, thus, the case for a clear contrast between the interests of doctors who look for the most effective technologies regardless of their costs and health managers that make choices in the attempt to fulfil budget constraints. More recently, Bech *et al.* (2009) examine the impact of economic and institutional factors on technology adoption on three procedures for treatment of heart attack patients for 17 countries over a 15-year period and their empirical findings suggest that different regulatory structures and remuneration schemes can impact on technology diffusion, even if the result for the impact of the remuneration system is not clear cut.

Our work contributes to the existing empirical literature by providing an econometric analysis of the relationship between the different reimbursement systems offered by Italian regions and the diffusion of medical technologies, focusing on medical equipment. We do not focus on specific technologies, since we will examine the overall endowment of different pieces of medical equipment in hospitals. Moreover, our empirical analysis will not use data at a single hospital level, but it is based on data on the overall regional endowment of medical equipment. In such a way, therefore, we can capture the effect of the overall financing mechanism, not just of single fees or funds, at the level of the overall (regional) health care system, not just for the single hospital technological decisions.

3. MECHANISMS FOR FINANCING HOSPITAL CARE IN ITALY

Italy may represent an interesting case study to test the impact of different financing mechanisms on the process of technology adoption. In this section, we will provide a brief overview of the financing system for hospital care in Italy and we will show that it is significantly differentiated in its regions.

In the Italian national health system public provision of hospital care takes place through different types of providers, public [1] as well as accredited private providers. The composition of supply is fairly differentiated across regions both with respect to the public-private mix and different types of public providers. Following one of the most important reforms of its health care sector in early 90s, Italy changed, among the other things, the financing mechanism for providers, until then mainly based on actual expenditure (Fattore, Torbica, 2006; Guccio, 2005; Anessi-Pessina, Cantù, Jommi, 2004). More specifically, as far as inpatient care is concerned, the basic criteria that, since the time of those reforms, are in use for determining the amount of money, which each hospital receives from the regional government, are[2]: i) lump sum transfers for specific health care services, ii) activity based payments[3]. As for the former, the services whose provision is financed through lump sum transfers include integrated care, prevention activities, emergency services, experimental programs, transplants. For all these services, "tariffs are deemed inadequate or inappropriate"[4] (Fattore, Torbica, 2006) and, therefore, they are financed, as said, through lump sum transfers that should be determined on the basis of the computation of the efficient costs of their provision. The rest of inpatient care is financed through a per case funding system, based on tariffs[5]. The tariff system is based on the DRG classification of discharges, version 24[6], and on a differentiation of ordinary, day hospital and day surgery cases.

It must be considered, however, that, for public hospitals directly managed by local health authorities, funding is unrelated to the previous criteria. Local health

[1] There are two main types of public hospital: *Aziende ospedaliere,* e.g. independent hospitals, and *Presidi ospedalieri,* e.g. hospitals run by local health authorities (*Unità sanitarie locali).* Local health authorities are administrative units, within each Region, responsible, in their geographical area, for the provision of the uniform package of health care services that has to be accessible to all citizens in the country. They enjoy managerial autonomy, under the control of regional governments.

[2] Legislative Decree 502/1992, Article 8-sexies.

[3] These criteria are also applicable to providers of ambulatory services.

[4] The inappropriateness of tariffs for financing this type of services is due to different reasons: some services, like transplants have a regional interest, since they are very few and require sophisticated technologies, so that they need to be concentrated in one or a few hospitals; other services, like the ones related to emergency, require an amount of resources independent of demand; there are peculiarities of some hospitals (like teaching hospitals) difficult to be dealt with in the tariff mechanism. See Morandi (2009).

[5] Outpatient services are financed according to a fee-for-service mechanism.

[6] This version was introduced, at a national level, in 2009 (see Morandi and Arcangeli, 2009).

authorities are generally funded by the regional governments according to weighted capitation[7], and they use these resources to finance services offered by other providers[8] (private and public ones) and to produce services directly, among which those provided by their own hospitals. Therefore, the activity of these hospitals is "… *de facto* financed on the basis of the consumption of production factors (personnel, goods and services, etc.)" (Morandi *et al.*, 2008 – our translation).

These are the fundamental pillars of hospital care financing in Italy. There is, however, a crucial characteristic that is related to the role of regional governments. The 90s reforms devolved the responsibility for the organization and financing of health care to Regions. This has relevant implications for the proportion of use of the two basic components of hospital care financing in each region. As for the lump sum payments to hospitals for the services not subject to tariffs, regions have full autonomy in the identification of the services which will be financed in this way, within the general category of services discussed above. Therefore, the choices they make in this area affect the relative weight in the overall financing of hospital care of forfeit versus activity based payments. There are no reliable data that allow to measure the relative extent of each source of funding for hospitals, but some of the few estimates available (for some regions) show that the percentage of hospital care expenditure financed through lump sum transfers ranges from a value as low as 1% in Umbria to 20% in Lombardy (see Morandi *et al.*, 2008). Other differences among regions are also related to the type of hospitals that receive funds through this channel. Most regions provide these funds only to public hospitals, but in a few ones private hospitals benefit from this financial source too.

As for the tariffs, there are several aspects related to their determination, which are left to the autonomy of regions. First of all, each region determines, along the

[7] Weights, when used, are generally related to age. The financing system of local health authorities, however, is quite differentiated across the regions, in terms of the criteria used for the allocation of the financial resources to each authority, but also for the amount of resources that each region decides to transfer to local health authorities. This topic, however, is out of the scope of this paper. For a recent survey of the different regional systems, see Morandi (2008).

[8] Some regions have mechanisms of direct funding of private and public independent providers, through their central administration. On this issue, see, among the others, Fattore and Torbica (2006), Guccio (2005), Pignataro and Rizzo (2005).

DRG classification, its own tariffs, on the basis of general criteria determined at a national level[9]. There is quite a high degree of variability across regions, as for the way they have determined their own tariffs. Only five regions (Lombardy, Veneto, Emilia Romagna, Tuscany and Umbria) have based their tariffs on the analysis of costs; other regions' tariffs are based either on the 1997 national tariffs (Piedmont, Valle d'Aosta, Trento and Bolzano) or on the 2006 national tariffs (Lazio, Campania, Puglia, Sicily and, partly, Abruzzo and Sardinia); Sardinia partly refers to the national tariffs that regulates the financial compensation between regions for the services provided by each region to residents of other regions[10]. Secondly, regions may differentiate their own tariffs by type of providers, according to their organizational and activity characteristics. Several regions have used this possibility, and most of them pay the maximum value of tariffs to hospitals that provide emergency services and, in some cases, to teaching hospitals, with a range of variability of tariffs which can go up to 25%[11]. The use of their own tariff systems by the regions creates relevant differences in their value. Morandi and Arcangeli (2009) run an exercise, comparing the potential expenditure arising from the application of the regional tariffs to the 2006 national record of discharges, with the one computed with the 2006 national tariffs. They find a variability range of about 45%. A third important feature characterizing the regional funding systems is related to the implementation of expenditure caps, ceilings and targets, so as to avoid the sort of "perverse" incentive to increase volume of services, generally associated to prospective payment systems (see Anessi-Pessina, Cantù, Jommi, 2004). There are, finally, other differences related to the reimbursement for rehabilitation services.

Summing up, Italian regions show relevant differences in their system for funding hospital care, which can have a significant impact on the adoption of medical technology. A first relevant difference is between the funding system for public

[9] A decree issued by the Ministry of Health on April 15, 1994 laid out these criteria, which can be traced back to full costing. On the 15th of December of the same year, the Ministry determined national tariffs, based on data collected from eight hospitals. These tariffs were updated, with a decree issued by the Ministry on June 30, 1997 and, more recently with another decree, issued on September 12, 2006.

[10] For more details, see Morandi (2008) and Morandi and Arcangeli (2009).

[11] There is the noticeable exception of Campania, which pays some of the private accredited hospitals only 57% of the maximum tariff.

hospitals directly managed by local health authorities and the one for all other hospitals (private accredited and public independent hospitals). While the former are financed through the budget of local health authorities, on the basis of the consumption of production factors, the latter are financed through tariffs and lump sum funds. The incentives to the adoption of medical technology, typically related to tariffs are not, therefore, acting for hospitals run by local health authorities. Regions show relevant differences in terms of the extent of supply of services from these hospitals, relatively to the overall supply: Lombardy, for instance, has no hospital run by local health authorities. The second difference, relatively to the funding of public independent and private accredited hospitals, is in terms of the relative extent of lumps sum funding for some services with respect to the overall resources transferred to these hospitals. The larger the portion of lump sum funding, the weaker the incentives arising from tariffs. We have already shown that there is a quite significant range of variability across regions, in terms of the identification of services to be financed by lump sum transfers. Finally, there are regional differences as far as the tariffs for each DRG category are concerned, with a potential impact on the incentive to adopt specific technologies.

The data available at a regional level do not allow a quantitative representation of the second and third type of differences in the regional financing systems, as explained above. As for the first one, related to the comparison of public hospitals run by local health authorities versus all the other hospitals, one way to represent the differences among regions is to consider, for each region, the ratio of beds used by hospitals not run by local health authorities (independent public and private accredited hospitals) with respect to the total number of hospital beds in the region. This indicator should provide a rough idea of the extent to which the tariff system is used, in each region, for financing hospital care. We are aware that it is not able to represent the actual extent of use of tariffs, since it does not capture the variability of lump sum funding across regions.

4. EMPIRICAL ANALYSIS

4.1 The measurement of the regional endowment of medical equipment

As it has been already stressed, our analysis is focused on medical equipment such as CT-scanners (Computed Tomography scanners) or MRI (Magnetic Resonance Imaging scanners) diffusion in hospital excluding new medical treatment technologies. Our work, thus, departs from the stream of literature, which takes into consideration a wider definition of medical technology (Mas and Seinfeld, 2008).

A relevant problem in carrying out an empirical work, examining the process of adoption of medical technology, refers to the issue of measurement of the technology adoption and diffusion. Spetz and Maiuro (2004) show that, when choosing how to measure the factors affecting medical technology adoption or diffusion, besides data availability and the proposed goals it is necessary to consider that the *"….analysis of individual technologies is limited by the idiosyncrasies of each technology's history, financing, and diffusion. Indices can ameliorate this problem but introduce their own problems. Indices can confound the data, as in the case of the Saidin index in which a hospital that adds five common services may have the same increase in the index as a hospital that adds one rare service….."*.

Almost all empirical works focusing on the factors affecting technology adoption analyse one or more technologies separately. Several technologies have been investigated such as MRIs (Baker and Wheeler, 1998), mammography facilities (Baker and Brown, 1997), neonatal intensive care units (Baker and Phibbs, 2002), coronary heart disease (Cappellaro et al., 2011) and heart attack treatments and angioplasty (Cutler and McClellan, 1996). Mas and Seinfeld (2008) look at 13 different medical technologies.

The most used approach to evaluate the diffusion of single medical technologies, at a country or a regional level, is to employ, for instance, an index computed in terms of number of devices or equipment per thousand or million inhabitants. These measures however take into account each technology one at time. For providing aggregate information about technology diffusion it is necessary employ an index, which summarizes technology availability. The work of Baker and Spetz (1999) is one of the few papers adopting aggregate indices to evaluate

technologies available to hospitals. The authors use an index of availability of hospital technology, Saidin index (Spetz and Maiuro, 2004), that weights hospital technologies on the basis of the complement of their rate of diffusion among the sample of hospitals under consideration, keeping constant the set of technologies. Thus, the less diffused the set of technologies, the higher the value of the weight will be[12].

However, the application of this index, that computes the weights of the different technologies on the basis of a dummy variable accounting for the presence/absence of each technology, would not be really useful with respect to the aggregate regional data we are using, which refer to a wide bundle of technologies. These data are affected by factors different from those influencing the technology adoption of a single hospital such as geographical dimension and population of the region, its socio-economic and health conditions, output mix and reimbursement system of health care providers.

Therefore, we will use an aggregate index of technology diffusion, computed as a weighted sum of the number of pieces of different types of equipment, available in the hospitals of each region, where the weights are represented by a vector of normalized prices. The index is computed per million population.

4.2 Data

Data from different sources are collected for this study. The unit of observation in this study is the region and we focus only on acute care hospitals. We use available data on regional endowment of 16 different medical equipment, in the period 1997-2007 (see appendix A, for the list of medical equipment and for the different sources of data). To compute the weights for our indicator, as described in the previous section, we employ data provided by the Italian Ministry of Health and the Observatory of prices and technologies (*Osservatorio Prezzi e Tecnologie*), regarding the prices of the different equipment. The technical details on the computation of weights and of the indicator are provided in appendix A. The explanatory variables are collected from two primary sources: ISTAT and the Italian Ministry of Health.

[12] To use Saidin index in a time series or panel data analysis, it is necessary to employ a fixed vector of weights with respect to a base year.

Table 2 shows the regional values of the indicator of endowment of medical equipment, computed for the public hospitals, for the private accredited hospitals and for the overall hospital sector. We have also computed the variation in the period of time considered in our analysis.

Table 2 – Index of regional endowment of medical equipment, per million population

Region	Index for public hospitals		Index for private accredited hospitals		Index for all hospitals	
	Mean	Δ % 1997-2007	Mean	Δ % 1997-2007	Mean	Δ % 1997-2007
Abruzzo	57.06	*81.32%*	15.57	*140.94%*	72.63	*93.20%*
Basilicata	52.09	*151.52%*	1.55	*166.54%*	53.64	*151.85%*
Calabria	46.22	*79.30%*	20.41	*95.79%*	66.63	*84.03%*
Campania	38.91	*69.83%*	16.05	*76.36%*	54.97	*71.79%*
Emilia Romagna	72.81	*251.79%*	14.33	*129.85%*	87.13	*223.41%*
Friuli V.G.	75.37	*18.31%*	7.21	*117.14%*	82.58	*24.81%*
Lazio	62.89	*85.44%*	18.06	*-8.81%*	80.95	*53.52%*
Liguria	77.95	*77.96%*	1.20	*4.70%*	79.15	*76.10%*
Lombardy	68.29	*41.92%*	15.89	*26.76%*	84.19	*38.96%*
Marche	77.83	*42.77%*	10.73	*64.99%*	88.56	*44.91%*
Molise	86.34	*209.81%*	11.10	*183.95%*	97.44	*206.35%*
Piedmont	65.20	*86.40%*	9.32	*248.66%*	74.52	*100.31%*
Puglia	54.87	*53.18%*	10.08	*57.48%*	64.95	*53.87%*
Sardinia	59.94	*131.28%*	10.89	*69.35%*	70.83	*119.57%*
Sicilia	49.86	*71.64%*	13.61	*97.12%*	63.47	*76.88%*
Toscana	74.37	*53.43%*	5.82	*25.98%*	80.20	*50.81%*
Trentino A.A.	89.50	*24.26%*	7.79	*40.74%*	97.29	*25.51%*
Umbria	83.60	*61.50%*	5.72	*11.77%*	89.32	*57.74%*
Valle d'Aosta (*)	86.14	*21.30%*	0.00	*0.00%*	86.14	*21.30%*
Veneto	73.99	*47.10%*	3.85	*57.17%*	77.85	*47.59%*
Total	**67.66**	***85.84%***	**9.96**	***70.67%***	**77.62**	***83.69%***

(*) Data for this region are available starting with 1998.

Note: data are weighted by population and the mean is computed across years
Source: our elaboration on data provided by Italian Ministry of Health and "Osservatorio Prezzi e Tecnologie".

Data reveal quite a strong variability of the values of the index, across the regions, in terms of both the overall availability of equipment and the public and private endowment. The dynamics of the indicator is also remarkably different in each region.

The index we have computed considers 16 different types of equipment, some of which are very different, at least in terms of prices. For instance, the ratio of the price of the most expensive equipment in our dataset (MRI) to the price of the least expensive one (haemodialysis delivery system) is about 100. Since the literature (among the others, Mas and Seinfeld, 2008 and Bech *et al*., 2009) shows that the price of technology plays a relevant role in its adoption, we have also focused on the four most expensive equipment in our dataset (linear accelerators and components, computerized gamma camera, CT – scanner and MRI), and we have computed our index for this subset of equipment. Table 3 shows the values of this index for each region.

Table 3 – Index of regional endowment of the four most expensive medical equipment, per million population

Region	Index for public hospitals		Index for private accredited hospitals		Index for all hospitals	
	Mean	Δ % 1997-2007	Mean	Δ % 1997-2007	Mean	Δ % 1997-2007
Abruzzo	14.91	*155.55%*	6.28	*124.15%*	21.19	*146.10%*
Basilicata	10.55	*477.91%*	0.59	--	11.14	*494.55%*
Calabria	11.22	*229.66%*	7.88	*133.90%*	19.10	*183.99%*
Campania	9.45	*135.50%*	5.65	*130.70%*	15.09	*133.57%*
Emilia Romagna	13.14	*419.03%*	5.51	*161.03%*	18.64	*311.16%*
Friuli V.G.	19.47	*53.04%*	2.52	*731.09%*	21.99	*79.70%*
Lazio	17.53	*132.03%*	7.01	*-3.20%*	24.54	*68.72%*
Liguria	19.30	*158.33%*	0.04	*-100.00%*	19.34	*153.33%*
Lombardy	15.61	*78.92%*	5.91	*18.21%*	21.52	*59.05%*
Marche	19.22	*132.08%*	3.35	*227.36%*	22.58	*140.18%*
Molise	23.81	*623.73%*	4.50	*237.45%*	28.30	*518.93%*
Piedmont	17.04	*118.47%*	3.93	*325.16%*	20.97	*145.26%*
Puglia	12.92	*105.84%*	3.75	*29.95%*	16.68	*82.82%*
Sardinia	15.33	*232.94%*	3.92	*95.54%*	19.25	*193.28%*
Sicilia	10.15	*149.75%*	5.26	*166.43%*	15.41	*155.33%*
Toscana	17.74	*133.81%*	1.18	*37.15%*	18.91	*122.85%*
Trentino A.A.	14.16	*69.82%*	3.35	*202.03%*	17.52	*88.88%*
Umbria	17.98	*123.88%*	1.48	*-16.77%*	19.46	*104.69%*
Valle d'Aosta (*)	19.53	*590.06%*	0.00	*0.00%*	19.53	*590.06%*
Veneto	17.61	*83.81%*	1.60	*119.19%*	19.21	*86.54%*
Total	**15.83**	**176.28%**	**3.69**	**103.23%**	**19.52**	*159.47%*

(*) Data for this region are available starting with 1998.

Note: data are weighted by population and the mean is computed across years
Source: our elaboration on data provided by Italian Ministry of Health and "Osservatorio Prezzi e Tecnologie".

Here again, it is possible to observe relevant differences across the regions, both in terms of endowment and of dynamics.

4.3 Empirical strategy and estimations results

In the above section we outlined that the endowment index and its variation through time vary considerably across regions. In this section we investigate the determinants of such a marked variability.

Following some of the conclusions reached in the literature overviewed in section 2, we assume our endowment index to be a linear function of demand, supply variables and regional financing system.

As for the demand variables, we employ real per capita income and the proportion of population aged 65 and over. As for the supply variables, we use total hospital beds per 1,000 inhabitants and the number of physicians working in hospitals per 1,000 inhabitants. We will also consider the impact of the potential competition from the private sector, as measured, in general, by the proportion of total beds owned by private accredited hospitals, and more specifically, with respect to the process of technology adoption, by the endowment index computed only for the private sector. As a proxy for representing the extent to which the DRG per case payment system is used in each region, as discussed at the end of section 3, we consider the proportion of total hospital beds owned by public independent and private accredited hospitals (the two classes of hospitals for which this financing mechanism is in use, even if at different degrees). Therefore, the estimated models have this general formulation:

$$Equipment\ endowment\ index_{it} = \beta_1 + \beta_2\, log(GDP)_{it} + \beta_3\, OLD_{it} + \beta_4\, BEDS_{it} + \beta_5\, PHYS_{it} + \beta_6\, DRG_{it} + \beta_7\, PRIV_{it} + \beta_8\, T\_PRIVATE_{it} + \varepsilon_{it} \quad [1]$$

where the subscript *it* refers to region *i* in year *t*; *GDP* is per capita gross domestic product; *OLD* is the percentage of population aged 65 and over; *BEDS* indicates the number of hospital beds per 1,000 inhabitants; *PHYS* is the number of physicians working in hospitals per 1,000 inhabitants; *DRG* is the proportion of

total hospital beds owned by public independent and private accredited hospitals; *PRIV* is the proportion of total beds owned by private accredited hospitals; *T_PRIVATE* is the equipment endowment index computed just for the private sector; v_i is the region-specific residual and $\varepsilon_{it} = \eta_i + v_{it}$ is the disturbance term. We also add a set of year dummy variables, to control for trends in technology availability over time and use robust standard error to control for potential heteroskedasticity. [13]

The list of variables is provided in table 4, while the summary statistics for these variables are reported in table 5.

Table 4 – List of the variables employed in the models

VARIABLE	DEFINITION
DEPENDENT VARIABLE	
T	Index of endowment of equipment per million population
T_PUBLIC	Index of endowment of equipment, per million population, of public hospitals
HT	Index of endowment of the 4 most expensive equipment per million population
HT_PUBLIC	Index of endowment of the 4 most expensive equipment, per million population, of public hospitals
INDEPENDENT VARIABLES	
GDP	Per capita gross domestic product at 2000 fixed prices
OLD	Percentage of population aged 65 and over
BEDS	Number of hospital beds per 1,000 inhabitants
PH	Number of physicians working in hospitals per 1,000 inhabitants
DRG	Proportion of total beds owned by public independent and private accredited hospitals
PRIV	Proportion of total beds owned by private accredited hospitals
T_PRIVATE	Index of endowment of equipment, per million population, of private accredited hospitals
HT_PRIVATE	Index of endowment of the 4 most expensive equipment, per million population, of private accredited hospitals
YEAR	Dummies for years

[13] Finally, as far as the estimation methodology is concerned, the results of the diagnostic for panel data (Breusch–Pagan's test and Hausman's test) suggest that the fixed effect model is not adequate for the nature of the data thus we follow the previous literature which generally assumes poolability of the data.

Table 5 – Descriptive statistics of the variables employed

Variable	Obs	Mean	Std. Dev.	Min	Max
T	209	77.17	18.69	32.23	144.20
T_PUBLIC	209	66.69	18.44	24.72	127.54
HT	209	19.52	6.70	3.58	49.29
HT_PUBLIC	209	15.64	5.89	3.58	42.00
GDP	209	22,415.07	6,758.42	10,334.27	38,755.31
OLD	209	19.53	2.98	13.02	26.74
BEDS	209	4.50	1.68	2.92	24.23
PHYS	209	1.97	0.26	1.14	2.72
DRG	209	0.50	0.20	0.01	0.99
PRIV	209	0.17	0.12	0.00	0.80
T_PRIVATE	209	10.48	5.99	0.00	25.01
HT_PRIVATE	209	3.88	2.63	0.00	11.49

Source: our elaboration on data provided by *by Italian Ministry of Health and ISTAT*

We estimate eight different specifications of model [1] using different dependent as well as independent variables.

The first two specifications refer to the regional endowment of both public and private hospital, using two different dependent variables: the overall regional endowment index (***T***), computed on the 16 different equipment in the dataset and the overall regional endowment index (***HT***), computed only for the four most expensive types of equipment. The results obtained are reported in table 6.

The other six specifications refer to public hospitals only and use two different dependent variables: overall regional endowment index (***T_PUBLIC***), computed on the 16 different equipment in the dataset, and overall regional endowment index for public hospitals only (***HT_PUBLIC***). For each of these two dependent variables we propose three different specifications, according to the inclusion or exclusion of the variables representing the role of the private sector. The results obtained are reported in table 7.

Table 6 – Determinants of technological index for the overall hospital system

VARIABLES	(1)	(2)
	T	***HT***
Constant	-233.5253***	-32.0373***
	(30.0496)	(10.2968)
GDP	26.0229***	2.4010*
	(3.7552)	(1.3022)
OLD	0.0728	-0.0481
	(0.3157)	(0.0991)
BEDS	1.7481**	0.4665
	(0.8596)	(0.3149)
PHYS	19.5936***	11.0799***
	(4.8941)	(1.8638)
DRG	-20.9866***	-5.7033***
	(4.2188)	(1.4152)
PRIV	-20.0370*	-3.4465
	(10.8530)	(3.7540)
Observations	209	209
Number of regions	19	19
Controlled for year	yes	yes
Year dummies (Prob>F)	0.0000	0.0000
R-squared	0.7249	0.7334

Notes: Robust standard errors are reported in parentheses.
***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

Table 7 – Determinants of technological index for the public hospitals sector

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
	T_PUBLIC	***T_PUBLIC***	***T_PUBLIC***	***HT_PUBLIC***	***HT_PUBLIC***	***HT_PUBLIC***
Constant	-234.5123***	-234.5322***	-250.8130***	-29.9058***	-29.8489***	-36.4735***
	(27.7655)	(27.7493)	(26.9603)	(9.1918)	(9.2700)	(8.8378)
GDP	25.6135***	25.6053***	27.8105***	1.9157*	1.9028	2.7581**
	(3.5292)	(3.5678)	(3.4197)	(1.1553)	(1.1771)	(1.1181)
OLD	0.7156**	0.7285**	0.8979***	0.2564***	0.2645***	0.3495***
	(0.2950)	(0.3065)	(0.2992)	(0.0861)	(0.0959)	(0.0999)
BEDS	2.9143***	2.9378***	0.8795*	0.8736***	0.8844***	0.2576*
	(0.8916)	(0.9803)	(0.4593)	(0.3085)	(0.3267)	(0.1554)
PHYS	10.3380**	10.1517**	11.8906**	7.5304***	7.4356***	7.3971***
	(4.5260)	(4.1362)	(4.7068)	(1.6409)	(1.4900)	(1.6252)
DRG	-16.9390***	-16.8575***	-24.8948***	-3.6077***	-3.5518***	-6.2704***
	(4.3740)	(4.0593)	(4.8334)	(1.2749)	(1.1799)	(1.5452)
PRIV	-52.1038***	-52.7494***	--	-16.0121***	-16.3477***	--
	(10.3252)	(13.7137)	--	(3.4810)	(4.3275)	--
T_PRIVATE	--	0.0201	-0.5473***	--	--	--
	--	(0.2236)	(0.1554)	--	--	--
HT_PRIVATE	--	--	--	--	0.0267	-0.3096**
	--	--	--	--	(0.1467)	(0.1230)
Observations	209	209	209	209	209	209
Number of regions	19	19	19	19	19	19
Controlled for year	Yes	yes	yes	yes	yes	yes
Year dummies (Prob>F)	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
R-squared	0.7497	0.7497	0.7209	0.7292	0.7292	0.6985

Notes: Robust standard errors are reported in parentheses.
***, ** and * denote significance at 1, 5 and 10 per cent levels, respectively.

Table 6 shows the estimation results of models for the overall ***T*** and ***HT*** indexes and table 7 the estimation results of models for the public sector ***T_PUBLIC*** and ***HT_PUBLIC*** indexes. The results are robust and with a high explicative power and generally in line with the main conclusions reached in the literature.

As expected, all demand related variables (***GDP***, ***OLD***) and supply variables (***BEDS***, ***PHYS***) are almost always significant and have a positive impact on the

endowment of equipment of regions, implying that technological endowment and its variation through time can be justified on one hand, as a response to the demand and, on the other hand, as an input in the production process.

Looking at the 'core' issue of this paper, e.g. the effects of the remuneration system, our results suggest that the per case payment system provides effective incentives to constrain technology adoption; in fact, the variable representing the proxy for the extent to which the per case payment system is used in each region (***DRG***) is significant and has a negative impact on the regional endowment of equipment. Indeed, budget constraints may be more stringent for hospitals paid in such a way, in terms of both the financial resources they get (very poor adjustment of the monetary values of tariffs during the time period considered) and of the incentive to cost control they provide for managers and doctors.

Finally, our results outline that the private sector has a negative impact on the regional endowment of equipment: the variables representing the role of the private sector in terms of the proportion of total acute beds owned by private accredited hospitals (***PRIV***) and of the overall endowment of equipment (***T_PRIVATE***) are significant with a negative sign. A plausible explanation relies on the low complexity of hospital care in private accredited hospitals (relevant for the result in the model with the total endowment as dependent variable) and on the substitutability between public and private equipment (relevant for the results in the models with public endowment as dependent variable).

The above results are robust for both indexes, whether computed on the 16 different equipment in the dataset or computed only for the four most expensive types of equipment.

5. CONCLUDING REMARKS

This paper represents a first attempt to analyse the determinants of equipment endowment in hospital sector in the Italian regions, where there are relevant socio-economic difference among geographical areas as well as different regulation of providers due to the high degree of regional autonomy in the health

care sector. We build up and indicator for measuring the regional endowment of medical equipment, based on a weighted sum of the number of equipment, where the weights are represented by a vector of normalized prices. We test the hypothesis that the differences across the regional reimbursement mechanisms, in terms of how extended is the use of the DRG system in the coverage of the overall financing of hospital care, impact on the change in the equipment endowment, as measured by our indicator. Our results suggest that the per case payment system provides effective incentives to constrain technology adoption, because of the related stringent budget constraints.

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Appendix - A

The main data source used in our empirical investigation are the Italian Ministry of Health and ISTAT. Table 1 report the description of variables employed and relative source.

Table A.1 - Description of variables and sources

Variables	Description	Sources
T	Index of endowment of equipment per million population	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
T_PUBLIC	Index of endowment of equipment, per million population, of public hospitals	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
HT	Index of endowment of the 4 most expensive equipment per million population	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
HT_PUBLIC	Index of endowment of the 4 most expensive equipment, per million population, of public hospitals	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
T_PRIVATE	Index of endowment of equipment, per million population, of private accredited hospitals	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
HT_PRIVATE	Index of endowment of the 4 most expensive equipment, per million population, of private accredited hospitals	Elaborated from Italian Ministry of Health data and "Osservatorio prezzi e tecnologie" database
GDP	Per capita gross domestic product at 2000 fixed prices	Elaborated from ISTAT data, health for all database
OLD	Percentage of population aged 65 and over	Elaborated from ISTAT data, health for all database
BEDS	Number of hospital beds per 1,000 inhabitants	Elaborated from ISTAT data, health for all database
PH	Number of physicians working in hospitals per 1,000 inhabitants	Elaborated from Italian Ministry of Health data
DRG	Proportion of total beds owned by public independent and private accredited hospitals	Elaborated from Italian Ministry of Health data
PRIV	Proportion of total beds owned by private accredited hospitals	Elaborated from Italian Ministry of Health data

Our aggregate index of technology diffusion is computed on the basis of the census of high technical equipment available in the acute hospitals of each region made by Italian Ministry of Health in the period 1997-2007. Table A.2 report the list of 16 medical equipment in our basket and the estimated weights. The reported weights are calculated on the basis of the prices of the different equipment employing data provided by Observatory of prices and technologies (*Osservatorio Prezzi e Tecnologie*).

Table A.2 – Acute hospital technical equipment.

Medical devices	Estimated price *	Weight	Relative prices
Automatic Immunochemistry System	25,490.73	0.0114	87.5876
Linear Accelerators and Components	1,490,187.65	0.6674	1.4982
Immunoassay Analyzer	66,707.05	0.0299	33.4698
Anesthesia Machine	57,644.96	0.0258	38.7315
Ultrasound system	209,999.90	0.0941	10.6318
Hemodialysis Delivery System	20,133.51	0.0090	110.8934
Computerized Gamma Camera	622,275.03	0.2787	3.5879
Differential Hematology Analyzer	53,210.39	0.0238	41.9593
Analog X-ray system	136,073.66	0.0609	16.4078
Surgical light	36,436.27	0.0163	61.2761
Monitor	47,993.70	0.0215	46.5201
Mobile X-ray system	139,782.09	0.0626	15.9725
CT - scanner	787,041.28	0.3525	2.8368
Magnetic resonance imaging (MRI)	2,232,673.02	1.0000	1.0000
Medical Imaging table	317,508.00	0.1422	7.0319
Continuous ventilator system	31,715.75	0.0142	70.3963

* On the basis of estimated price (at 2000 fixed prices)