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Diffusion of medical technology: The role of financing

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ABSTRACT

In the last decade the pace of innovation in medical technology has accelerated: hence the need to better identify and understand the real forces behind the adoption and diffusion of medical technology innovations in clinical practice.

Among these forces, financial incentives may be expected to play a major role. The purpose of this paper was to assess the influence of financing mechanisms for new medical devices and correlated procedures on their diffusion. The analysis was carried out in the Italian inpatient cardiovascular area and applied to drug eluting stents over the period 2003–07.

The paper's main hypothesis, that higher levels of reimbursement encourage technology diffusion, was rejected. So was the hypothesis that private hospitals may be more sensitive to tariff levels than public hospitals. A statistically significant difference was found only between hospitals that are funded on a Diagnosis-Related Groups (DRGs) basis and those that are not, with the former showing higher levels of technology diffusion.

These results warn policy makers against excessive reliance on specific reimbursement fee changes as a way of steering provider behaviour.

1. Introduction

The rapid pace of innovation experienced by medical technology in the last decade has increased the range of alternatives for the prevention and treatment of disease [1]. New technologies have been proven effective at improving care and health outcomes in terms of both survival rates and quality of life [2–4]. Although often cost-effective, these technologies have contributed to the rise in health care spending. As a consequence, governments have attempted to steer and regulate their diffusion.

The long-term effects of government policies on technology uptake, however, remain to be investigated. The identification and understanding of the real forces behind the adoption and diffusion of medical technology innovations in clinical practice are of vital importance not only from a theoretical viewpoint, but also from a public policy perspective, since they would provide a stronger evidence basis for future policymaking.

Theories on technology innovation have addressed the diffusion question, exploring the economic and social conditions that affect the spread of innovations [5]. In the health care context, theoretical contributions have hypothesized that the diffusion of medical technologies, at any time and over time, is shaped by a multiplicity of determinants acting at the professional, organizational, and regulatory levels [6].

At the professional and organizational levels, empirical studies have emphasized the influence of social interaction

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and environmental conditions on both the timing of adoption and the pattern of diffusion of medical technologies. In particular, increasing attention has been paid to the role of physicians' informational externalities [7], expert power [8,9], and clinical excellence [10].

At the regulatory level, supply-side incentives – most notably payments to providers – are generally expected to play a substantial role. The presence and the amount of reimbursement for the use of technologies, in particular, are expected to affect provider behaviour. Recent studies, for instance, have traced the cross-country variations in the diffusion patterns of medical technology back to differences in national regulatory policies and payment systems for provider organizations and physicians [8,11,12]. The interest for the implications of specific payment systems has been further reinforced by the diffusion of prospective case-fee reimbursement mechanisms for inpatient care based on Diagnosis-Related Groups (DRGs) [13,14].

The extent to which case-fee payments affect the uptake of medical technology innovations, however, is still underdetermined. Fixed global-budget schemes have generally been expected to slow down the speed of technological change [12,15,16], especially if based on historical incremental criteria. In contrast, DRG systems have been argued to enhance the financial accountability of provider organizations and their individual units [17]. This should induce hospitals to adopt and use innovative technologies that are net-beneficial to the hospitals themselves [18] and, if the payment system is correctly designed to align organizational incentives with system-wide goals, also to the health-care system (or even society) as a whole.

Recent studies have also shown that responsiveness to financial incentives depends on the nature of medical technology. Diagnostic procedures are deemed more responsive than lifesaving devices [12], and high-technology changes – e.g. innovations with high fixed costs to adopt or high variable costs per use, such as invasive heart attack treatments – more than low-technology ones [11]. Another difference between high and low-technology changes is that financial incentives tend to affect the timing of adoption for the former, the extent of adoption for the latter [19].

While there has been considerable debate on the features of financing systems and their impact on overall hospital behaviour [18–21], only few empirical studies have investigated the relationship between payment systems and innovation diffusion for specific technologies. Shih and Berliner [22] analyze the impact of Medicare payments on the diffusion of stents. Their study compares the increase rates for bare metal stents usage among Medicare beneficiaries before and after the reimbursement changes introduced by the Centers for Medicare and Medicaid Services (CMS). Increased payment was not found to be an explicatory factor in the technology's diffusion. Findings to date, however, refer predominantly to the US. Furthermore, they are based on aggregate data at a system-wide level, and therefore fail to trace the diffusion patterns at the individual hospital level and to capture the effects of specific reimbursement mechanisms and payment levels across providers and over time.

Given these premises, the principal aim of this paper is to shed further light on the impact of reimbursement mechanisms on the diffusion of new medical devices and related procedures in a European setting, focusing on Italy. The paper is organized as follows. Section 2 provides the background for the study. Section 3 states the research objectives. Section 4 presents data and methods. Section 5 reports the results. Finally, Section 6 discusses the theoretical and policy implications of the study.

2. Background

2.1. Coronary heart disease and drug-eluting stents

This study deals with the treatment of coronary heart disease, one of the major causes of death in Western countries [23] and among the diseases with the steepest increases in prevalence rates, ultimately influenced by the sharp rise of associated risk factors such as smoking and obesity. Coronary heart disease is thus the clinical area in which equitable access to highly innovative technology can be expected to receive the greatest attention from health policy makers both at the national and European levels.

Specifically, this paper focuses on coronary drug-eluting stents (DES). Coronary stenting was introduced in clinical practice in the early 1990s for the treatment of obstructive coronary artery diseases during percutaneous transluminal coronary angioplasty (PTCA) procedures. At the time, bare metal stents (BMS) had been demonstrated to be more effective than ordinary balloon angioplasty in reducing restenosis rates, i.e. the re-narrowing of the coronary artery in the years following angioplasty. However, clinical evidence had shown that BMS induced an excessive vascular neointimal proliferation, thus increasing the risk of in-stent restenosis [24] and requiring re-interventions in a relevant percentage of patients [25]. In light of clinical trials, new coated stents (DES) were developed capable of releasing a medication that prevented in-stent restenosis. DES rapidly spread as a distinct device and were acknowledged as a breakthrough innovation in the current clinical practice of coronary disease treatment [26].

2.2. The Italian National Health Service

The analysis has been carried out in the Italian National Health Service (INHS).

The INHS covers the entire Italian population, is tax-funded, and provides most care free of charge at point of service [27]. It has three tiers: the Central government; 21 Regional governments (henceforth referred to as "Regions") with jurisdiction over most health care issues; 146 Local Health Authorities (LHAs) and 113 Independent INHS Hospitals (IHs, similar to British NHS Trusts). In addition to LHAs and IHs (henceforth referred to as "public providers"), providers include private hospitals and professionals. Private providers meeting specific requirements may apply for accreditation from the relevant Region, thus becoming eligible for INHS reimbursement.

Each year, the Central Government decides how much to spend on health care. It then ensures that each Regional Government can count on roughly the same amount of

adjusted per-capita funding. Regional Governments, in turn, are responsible for allocating the funds to public and accredited private providers. To this end, they rely on two main mechanisms: capitation and activity-based reimbursement.

More specifically, the Regional Government allocates the large majority of funds to LHAs, each of which is directly responsible for the provision of comprehensive care to its entire resident population. Once again, the allocation is based on adjusted capitation. Each LHA then variously combines two options: (i) provide care directly with its own personnel, hospitals and other facilities; or (ii) reimburse other LHAs, IHs, and accredited private providers for care given to its residents. Reimbursements are "activity-based", that is, DRG-based for inpatient care and fee-for-service for outpatient care. For inpatient care, therefore, IHs and accredited private hospitals are funded on a DRG basis, while hospitals that are directly managed by LHAs have their expenses covered by a share of the relevant LHA's capitated funding.

DRG tariffs are based on the "standard production cost of services", which comprises all the direct, indirect and overhead costs required to treat the patient, including physician salaries and other labour expenses. A national DRG fee schedule does exist, but the Regions have been allowed to modify it in terms of both classification and amounts, including (i) the differentiation of amounts across different types of hospital within the Region, and (ii) the introduction of cost-based add-on reimbursements, on top of DRG fees, for the use of particular medical devices. Given the variety of payment schemes at work across and within Regions, Italy provides an excellent case study for investigating the relations between new technologies and financial incentives.

2.3. The evolution of the payment system for DES in the INHS

The first model of DES – the sirolimus eluting stent, SES – was approved at the European level in April 2002 [26] and became marketable in Italy with no differences across Regions as to the timing of approval. At that time, the official national DRG classification was based on Version 10 of the HCFA Grouper. The procedures of stent insertion into coronary vessels – both BMS and DES – were classified according to the International Classification of Diseases, Ninth Revision (ICD-9) and assigned the code 36.06. However, no specific DRG category existed for the new DES procedure. Rather, one DRG (namely DRG 112) was used to reimburse all percutaneous interventions on the cardiovascular system, including balloon angioplasty, PTCA with insertion of BMS, and PTCA with insertion of DES.

As previously mentioned, however, Italian Regions were free to develop their own fee schedules. These schedules differed from the national one in terms both of classifications (CMS – formerly HCFA – Grouper Version N. 10, 14, or 19) and fee levels. In 2003, the first year following DES introduction in Italy, almost all Regions reimbursed the use of DES through the undifferentiated DRG 112. However, the Regions adopted different policy measures to account for the higher cost of the technology, including either an increase in the DRG tariff, usually differentiated across classes of provider, or the introduction of add-on payments on top of the DRG tariff. These add-on payments, in turn, were set according to different criteria. Lazio, for instance, linked them to the ratio of the number of coronary revascularization procedures performed to the number of Acute Myocardial Infarction (AMI) episodes occurring within the LHA. Puglia, conversely, reimbursed 25% of the DES list price to private accredited hospitals, but only in exchange for a 20% cut in DRG 112's tariff. Only the most populated Region, Lombardy, modified the regional fee schedule according to the updated CMS Version, N. 19. The new classification explicitly recognized stent reimbursement through the creation of two separate DRGs. Elective procedures were reimbursed by DRG 517 ("Percutaneous interventions on the cardiovascular system with insertion of stent in the coronary artery without AMI"). For emergency hospitalisations, the procedure of stent insertion was assigned to DRG 516 ("Percutaneous interventions on the cardiovascular system with AMI").

In the following years, regional reimbursement mechanisms for DES evolved in three directions. Firstly, Regional authorities updated the tariffs, with large regional differences in the frequency of such updates – from one year in Lombardy, to three (e.g. in Lazio, Puglia, and Tuscany) or even four years (in Sicily). Secondly, an increasing number of Regions introduced add-on payments, either as fixed amounts (e.g. €300 in Campania) or as a percentage of the device's cost (e.g. 50% in Lombardy). Finally, starting January 1st 2006, almost all Regions adopted CMS Version N. 19, following an agreement reached by the Regions with the Central Government. With the adoption of the updated Grouper, two Regions (Piedmont and Campania) further split DRG 517 between PTCA with BMS (517-A) and PTCA with DES (517-B), recognizing a higher tariff to the latter.

The analysis of the DES case in the INHS is thus interesting for at least two reasons. Firstly, the Italian health care financing system gradually evolved from an implicit to an explicit recognition of the technology, ultimately supported by the introduction of an ad hoc DRG for elective stenting procedures at the national level and a specific sub-code for DES in two Regions. Secondly, notable cross-regional differences exist in (i) the number of DRG-funded hospitals (IHs and accredited private providers) vis-à-vis LHA-managed hospitals, (ii) the level of DRG fees, and (iii) the presence and amounts of add-on reimbursements. This should provide enough variation to investigate thoroughly the reimbursement system's impact on the diffusion of the technology and its incorporation into standard practice.

3. Research aims

Technology diffusion is affected by many different factors originating at the professional, organizational, and regulatory levels [6,19]. While acknowledging the relevance of all these factors, this paper focuses on financing mechanisms. More precisely, the general issue we investigate is not whether financing mechanisms are the only factors affecting medical technology diffusion, but rather whether they play any significant role.

We focus on funding because policy makers have been devoting increasing attention to payment systems as a (direct) lever to steer provider behaviour. By isolating this regulatory factor, we aim to provide the research and policy communities with an assessment of the impact of different reimbursement alternatives on the diffusion of a particular medical technology, namely DES. More specifically, we examine two research questions.

The first question investigates the impact of different *types* of reimbursement schemes. As explained in Section 2.2, some Italian hospitals (i.e. IHs and accredited private providers) are funded on a DRG basis, while others (i.e. LHA-managed hospitals) are not. The first research question is whether the magnitude of adoption of new technologies differs between "DRG" and "non-DRG" hospitals.

To interpret correctly the results, one needs to consider that the reimbursement system tends to reflect the nature of the hospital, i.e. globals budget are applied to publicly run hospitals performing predominantly generalist functions. It is thus impossible to completely isolate the impact of the reimbursement system from other equally important organizational features affecting hospital behaviour. Results from this part of the analysis should be interpreted in this spirit.

If financial incentives play a role in the decision to adopt a new technology, higher expected profits should induce higher adoption rates. The second research question consequently investigates the influence of the *level* of reimbursement, testing whether higher DRG tariffs are associated with a significantly higher magnitude of DES adoption, all other provider features being equal. Obviously, this second question only applies to DRG-funded hospitals.

In other words, the first question investigates the impact of hospital reimbursement systems in a broad sense; the second question addresses more specifically the quantitative role of DRG tariffs in the diffusion of DES.

4. Materials and methods

4.1. Materials

The study uses data retrieved from multiple sources. Information on stenting implants was obtained from the database of the Italian Society of Invasive Cardiology (GISE) [28]. Since 2001, this database has been routinely used to record and publish the activities of Italian catheter laboratories, including diagnostic procedures, coronary angioplasty, peripheral percutaneous transluminal angioplasty (PTA), and paediatric invasive operations. Thus, the sample focuses explicitly on providers that already performed PTCA (and PTCA with BMS) procedures as part of their day-to-day activities. For this paper, the analysis was restricted to the section on coronary angioplasty for the period 2003–07.

Data on financing schemes were retrieved from Regional sources, including Regional laws, regulations and official fee schedules.

Data on hospitals' structural characteristics were obtained from the National Department of Health. For each year, data were collected on each hospital's (i) legal status (LHA-controlled, IH, accredited private investor-owned, accredited private religious), (ii) teaching status, (iii) number of beds, and (iv) case mix index.

Data were combined to form a single coherent data set. Nine Regions were included in the analysis (Piedmont, Lombardy, Veneto, Emilia-Romagna, Tuscany, Lazio, Campania, Puglia, and Sicily), accounting for about 80% of the overall Italian population [29]. Hospitals were classified as "DRG" or "non-DRG" according to whether they are funded through a perspective, DRG-based payment system. DRG hospitals include all IHs and all accredited private providers. On the contrary, LHA-controlled hospitals are "non-DRG" in that their expenses are covered by the relevant LHA with a share of its capitated global budget. Catheter labs belonging to the same hospital were drawn together to form a single unit of analysis. A total of 187 hospitals were included in the analysis.

Table 1 reports some descriptive statistics.

4.2. Methods

The dependent variable for the analysis is the DES diffusion ratio π, i.e. the proportion of procedures using DES over the total number of PTCA procedures. Fig. 1 shows the yearly value of the DES diffusion ratio, overall and separately for DRG and non-DRG hospitals.

Fig. 1 shows that, in 2003, DES diffusion was similar in DRG and non-DRG hospitals. More precisely, the mean difference in the DES diffusion ratio between the two groups of hospitals was small and not statistically significant (95% CI: −.099 to .019). The figure also shows that, between 2003 and 2007, DES diffusion differed across the two types of hospitals. However, a more formal analysis is needed to control for observable hospitals characteristics and statistically confirm this difference.

The most straightforward way of formalizing the existence of a significant difference in DES diffusion between DRG and non-DRG hospitals (thus tackling the first research question) is a "treatment-control" approach. Formally, the test is implemented through the following general model:

$$\Delta\pi_i = \vartheta C_i + \delta Z_i + \varepsilon_i$$

where the subscript i is for the hospital; $\Delta\pi$ is the first difference between the DES diffusion ratio in 2007 and 2003 for each hospital; C is a dummy for "non-DRG" hospitals; Z is a series of hospital related characteristics. The parameter of interest is ϑ: a negative (positive) and significant value of ϑ would imply that, compared to DRG hospitals, non-DRG ones are averagely less (more) likely to adopt DES.

It is worth noticing that the dependent variable is the first difference of the DES diffusion ratio for each hospital. The rationale for this choice is two-fold. First, by taking first differences, hospital fixed effects are differenced out [30]. In other words, one should not worry about the relation between unobservable time-invariant hospital characteristics and the DES diffusion ratio. Secondly, as noted above, the starting levels of DES adoption were similar across hospitals. Hence, any difference in DES diffusion will be reflected in a different growth of DES adoption between

Table 1
Main descriptive statistics.

Hospitals by main financing scheme ($n = 187$)		
	N	%
DRG hospitals – public	73	39
DRG hospitals – private, investor owned	36	19
DRG hospital – private, religious	16	9
Non-DRG hospitals	62	33
Hospitals by geographic area ($n = 187$)		
North	83	44
Center	50	27
South	54	29

Hospital activities ($n = 187$)			
	Min	Max	5-year mean (median)
DES diffusion ratio	0	1	0.38 (0.37)
Fee for DRG elective[a]	€4,957.99	€8,181.53	€6,570.91 (€6,640.56)
Fee for DRG emergency[a]	€4,957.99	€9,811.5	€7,137.15 (€7,297.84)
Beds	36	2,051	484 (486)
Case Mix Index	0.5	2.56	1.14 (1.07)
DES per procedure	0	4.78	1.62 (1.34)

[a] DRG Elective: DRG 112 for CMS grouper V.10/14 and DRG 517 for CMS grouper V.19. DRG emergency: DRG 112 for CMS grouper V.10/14 and DRG 516 for CMS grouper V.19.

2003 and 2007. Taking first differences in this sense seems a natural approach.

This kind of analysis could only be performed on the subset of 151 hospitals that were observed over the entire 5-year period. Hospital characteristics were controlled for using three variables: number of beds, case mix index, and a dummy for ownership status (private = 1). Since the hospitals were located in nine Regions, a set of eight regional dummies was also introduced, in order to control for common unobserved regional effects, mainly related to the different regional health care systems.

To address the second research question – i.e. whether, under the same payment mechanism (DRG), the adoption of new technology is influenced by the *level* of tariff reimbursement – non-DRG hospitals were excluded from the analysis and panel data regression techniques were applied to the sub-sample of DRG hospitals ($n = 125$). In its generalized linear model form, the equation to be estimated is written as follows:

$$\pi_{it} = \alpha_i + \beta DRG_{it} + \gamma X_{it} + \delta Z_i + \omega D_t + u_{it}$$

where subscripts i and t are for the hospital and the year. The vector DRG includes three hospital-specific, time-dependent variables characterizing the level of reimbursement: the DRG fee for elective procedures (DRG 112 for CMS Grouper V.10/14 and DRG 517 for CMS Grouper V.19), the DRG fee for emergency procedures (DRG 112 for CMS Grouper V.10/14 and DRG 516 for CMS Grouper V.19), and a dummy for hospitals receiving an add-on reimbursement for DES usage. X is a set of other observable hospital-specific, time-dependent variables: bed capacity, case mix, and the average number of DES implanted in each PTCA-with-DES procedure. Z is a set of time-invariant hospital characteristics: a dummy for ownership (public or private), one for teaching status, and another eight to identify the Region where the hospital is located. In some specifications, private hospitals were further classified as "investor owned" or "religious", since investor-owned hospitals may be more sensitive to tariff levels than both public and religious hospitals. As consequence, the dummy for private was replaced by a dummy for "investor owned" and an interaction term between this dummy and the elective DRG tariff. D is series of time dummies. Finally, u is the error term. For the purpose of this paper, the parameter of interest is β. A statistically significant value of the parameter would imply that

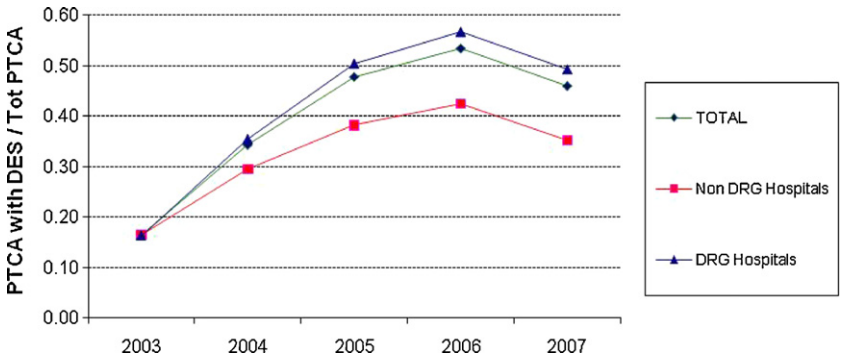

Fig. 1. DES diffusion ratio by hospital reimbursement type.

Table 2
Variables included in the panel data analysis.

Type of variable	Variable name	Variable description	Meaning of variable	Nature of variable	Data Source
Hospital-specific, time-dependent variables characterizing the level of tariff reimbursement (DRG_{it})	Elective DRG	CMS Grouper V.10/14: DRG 112 CMS Grouper V.19: DRG 517	DRG fee for elective procedures provided by hospital i in year t	Continuous	Regional fee schedules
	Emergency DRG	CMS Grouper V.10/14: DRG 112 CMS Grouper V.19: DRG 516	DRG fee for emergency procedures provided by hospital i in year t	Continuous	Regional fee schedules
	Add-on payments	Add-on reimbursements for DES implants provided by hospital i in year t		Dummy	Regional regulations
Other hospital-specific, time dependent variables (X_{it})	Beds	Total number of beds in hospital i and year t		Integer	National Department of Health's databases
	Case Mix	Case mix index in hospital i and year t		Continuous	National Department of Health's databases
	DES p.p.	Des per procedure	Average number of DES implanted during each PTCA procedure with DES in hospital i and year t	Continuous	GISE databases
	PTCA	Number of PTCAs that used at least one stent (BMS + DES)		Integer	GISE database
Hospital-specific, time-invariant variables (Z_i)	Region	Piedmont (baseline), Lombardy, Veneto, Emilia Romagna, Tuscany, Lazio, Campania, Puglia, Sicily	Hospital i's geographical location	Dummy set	National Department of Health's databases
	Private	Hospital i's ownership (private accredited = 1, public = 0)		Dummy	National Department of Health's databases
	Teaching	Hospital i's teaching status (teaching = 1; non-teaching = 0)		Dummy	National Department of Health's databases
Time dummies (D_t)	Y-2004	2004	Year t of observation	Dummy set	
	Y-2005	2005			
	Y-2006	2006			
	Y-2007	2007			

Table 3
DES adoption for DRG vs. non-DRG hospitals.

	(1)	(2)	(3)
Non-DRG	−.124 (.037)**	−.115 (.040)**	−.108 (.049)*
Beds		−.00009 (.00004)*	−.00006 (.00004)
Case Mix		−.086 (.063)	−.068 (.067)
Private		.022 (.051)	−.054 (.051)
Regional dummies	No	No	Yes
R^2	.07	.153	.26

Dependent variable: $\Delta\pi$ = first difference between the DES diffusion ratio (PTCAs with DES/total PTCAs) in 2007 and 2003.
** Significant at 1% level.
* Significant at 5% level.

financial incentives have affected the diffusion of DES. The variables included in the analysis are presented in Table 2.

The model describes a typical panel data regression, where α_i can be treated either as a hospital-related fixed effect or as a random effect uncorrelated with the error term. In order to provide robust results, various estimation approaches were used. Since only few hospital-related variables are observed, the initial step was a Fixed Effect (FE) panel regression [35], which focused on the impact of fee changes over time within hospitals. This was supplemented by the Fixed Effect Vector Decomposition (FEVD) model [31], which allowed for hospital-specific, time-invariant variables to be estimated within a Fixed Effect context. Although the choice between Fixed and Random Effects in linear panel data analysis is often crucial, it becomes much less important if the two approaches yield similar results. Therefore, the analysis was extended to include Random Effect (RE) panel data regression. Finally, noting that the error term showed relatively high levels of autocorrelation ($\rho = 0.7$), the RE model was corrected using an AR1 error structure.

5. Results

5.1. Types of reimbursement schemes

Results for the first research question are reported in Table 3. Overall, the data show a statistically significant difference between DRG and non-DRG hospitals. This is confirmed by both a simple analysis of variance (column 1) and a more complex specification controlling for confounders (column 2). More specifically, the average difference in DES diffusion growth between DRG and non-DRG hospitals is about 0.1, which corresponds to 30% of the average growth in DES adoption ratio over the five years of observation. Statistical significance is reduced once the regional dummies are included (column 3), but the relevant coefficient remains significant at the 95% level.

5.2. Tariff levels in DRG-based schemes

Results from the panel data analysis addressing the second research question are presented in Table 4. The first and second columns show the values and the standard errors of the coefficients obtained through FE and FEVD, while columns three and four refer to RE estimations, without and with the correction for autocorrelation, respectively. Time dummies are always included. Regional dummies are included wherever possible, but not reported. The results are particularly robust to the different specifications.

The coefficients for both Elective-DRG and Emergency-DRG are very close to zero and never significant. The coefficient for Add-on payment is also never significant. These results imply that DES diffusion in Italy has not been significantly driven by the levels of reimbursement associated with the technology.

Table 4
Tariffs and DES adoption.

	FE (1)	FEVD (2)	RE (3)	RE-AR1 (4)
DRG-elective	−1.00e−05 (.00003)	−1.64e−06 (.00002)	−.00003 (.00003)	−1.00e−05 (.00003)
DRG-emergency	−1.00e−05 (.00002)	−1.00e−05 (1.00e−05)	−4.42e−06 (.00002)	−4.00e−06 (.00002)
Add-on payment	−.026 (.023)	−.008 (.017)	−.032 (.018)	−.031 (.020)
Investor-owned		−.288 (.033)**	−.160 (.076)*	−.096 (.089)
Interaction (Investor-owned, DRG)	.00004 (.00002)	.00003 (5.21e−06)**	.00002 (1.00e−05)	1.00e−05 (1.00e−05)
DES p.p.	−.045 (.021)*	−.026 (.014)	−.015 (.020)	−.026 (.018)
Teaching		.075 (.012)**	.033 (.029)	.033 (.035)
Beds	−.0002 (.0009)	−.0002 (.0002)	2.49e−06 (.00003)	−.00002 (.00003)
Case Mix	−.005 (.069)	−.009 (.020)	.027 (.039)	.024 (.040)
Year dummy 2004	.156 (.017)**	.155 (.015)**	.160 (.017)**	.170 (.013)**
Year dummy 2005	.332 (.017)**	.329 (.015)**	.336 (.017)**	.345 (.017)**
Year dummy 2006	.439 (.020)**	.433 (.017)**	.428 (.020)**	.437 (.022)**
Year dummy 2007	.371 (.023)**	.363 (.019)**	.355 (.022)**	.365 (.025)**
LL	493.167	485.164		
R^2	.652	.781		

Dependent variable: π_{it} = DES diffusion ratio (PTCAs with DES/total PTCAs) in hospital i and year t.
** Significant at 1% level.
* Significant at 5% level.

The dummy for private hospitals (used in some specifications, but not reported) was never significant. The alternative dummy for investor-owned (i.e. private and non-religious) hospitals is sometimes significant (FEVD and RE) and always negative. The interaction is statistically significant only in the FEVD model, but its coefficient is very close to zero. Overall, it seems safe to claim that investor-owned hospitals use fewer DES than their public and religious counterparts, but are equally insensitive to tariff levels. On the other hand, teaching hospitals use slightly more DES than average, although the difference is not robustly significant.

Among the other explanatory variables, the most significant are the time dummies. The values of the time coefficients are generally very stable and highly significant across all the estimation techniques. A growing trend in DES adoption seems to have affected the whole country, at least until 2006. In 2007, the dependent variable drops. This decrease was mainly due to the rise of concerns, within the international professional community, both for the long-term safety of DES (see World Congress on Cardiology 2006) and their cost-effectiveness compared to BMS (see 2007 NICE appraisal).

Another important variable (at least in the FE estimations) is the number of DES per procedure (*DES p.p.*), whose coefficient is always negative. Finally, the hospital's number of beds and case mix were never significant.

6. Discussion and policy implications

In the last decade, the pace of innovation in medical technology has accelerated: hence the need to better identify the real forces behind the diffusion of new medical technologies in clinical practice. The purpose of this paper was to isolate the impact of financing mechanisms on the magnitude of diffusion of a new medical device in the cardiovascular setting, i.e. coronary drug-eluting stents (DES). The analysis was carried out in the Italian National Health Service (INHS), which provided enough variation of payment systems across Regions and over time to produce robust results.

In the INHS, the period 2003–07 was characterized by substantial cross-provider differences in the adoption of DES, despite a generalized increase. The first research hypothesis, that the magnitude of adoption of new technologies at the hospital level depends on the hospital's reimbursement system, was supported. A statistically significant difference was found between the hospitals that are funded on a perspective DRG basis and those that rely on a global budget, with the former showing higher levels of technology diffusion. Although this conclusion is fairly consistent with the existing literature [19], its interpretation is rather unique to our research setting, due to the institutional features of the INHS previously discussed.

The next logical step was to verify whether, among hospitals that are funded on a DRG basis, higher DRG fees would induce higher levels of technology diffusion. This second hypothesis, however, was not supported. Contrary to expectations, no significant relation was found between the amount of DRG fees and the magnitude of technology diffusion among Italian hospitals. One possible explanation for this result lies in the payment schemes for physicians – the primary decision makers in the adoption of new technologies. Physicians are employed by their health-care organization and receive a salary, the amount of which is constrained by National Collective Labour Agreements and largely depends on the physician's seniority and organizational position. Only about 10% of a physician's gross salary is result-based [32]. Under these circumstances, payment arrangements seemingly matter only in that physicians in DRG-funded hospitals are aware both that hospital funding will depend on the volume and mix of services provided, and that higher hospital revenues may also benefit themselves, directly through performance-related pay or indirectly through the greater professional opportunities that a richer hospital can offer. On the contrary, the specific amount of the DRG fee reimbursing the technology may not be an equally strong incentive.

The study has a few limitations that need mentioning. First, the analysis focuses on a specific dimension of technology diffusion, i.e. the magnitude of adoption. As remarked by the literature [19], medical diffusion is the product of a two-stage decision process: hospitals first decide whether to adopt the technology and then choose the magnitude of its adoption. In our data, however, the timing of adoption does not seem to play an important role. In December 2003, i.e. only eighteen months after the launch of the first DES model, 82% of the hospitals in the sample had already adopted the new technology. In this setting, a study that focused on the timing of adoption would not add much and would be virtually unfeasible, since data on stenting implants are recorded on an annual basis.

Secondly, our results are country-specific. Italy certainly provides an interesting research setting in that it offers a significant variation in the types and levels of financial incentives for hospitals. At the same time, the institutional peculiarities of the INHS – including the traditional presence of large geographic inequalities, recently exacerbated by the devolution of powers over most health care issues to the 21 Regions – may decrease the generalizability of the conclusions.

Third, the selection of the control variables to be included in the model was constrained by data availability issues, which the focus on individual hospitals made particularly stringent. Future research should tackle this limitation, for example by quantifying and controlling for the role of non-financial determinants such as clinical excellence and technology imperative.

At the same time, the study provides a number of contributions for both researchers and policy makers. From a research viewpoint, these results contribute to the recent literature on financing systems and innovation diffusion [22], by extending the analysis to the micro level of the individual provider and to a European setting. From a public policy perspective, our results provide policy makers with robust evidence on the limited effectiveness of fee setting *per se* as a way of steering provider behaviour in a public health-care system. While it is now commonly acknowledged in the literature that medical technology diffusion is a dynamic process involving a wide range of stakeholders with multifaceted motives at different lev-

els, the widespread tendency by public authorities to focus on the sole economic dimension risks being unhelpful and often counterproductive.

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