Innovation diffusion under budget constraints

Microeconometric evidence on heart attack in France[*]

Brigitte Dormont[†]and Carine Milcent[‡].

Preliminary version

18 février 2004

Abstract

This paper studies the relationship between the diffusion of innovative procedures for the treatment of heart attack and the distributions of the cost and length of hospital stays. Using a sample of 5,681 stays observed in French publics hospitals, we use microsimulation techniques in order to highlight various effects on the shifts in the overall distributions of the costs and length of stays : (i) the effect of the adoption of new techniques by hospitals (*between* hospital diffusion) ; (ii) the effect of the diffusion of technological progress *within* hospitals ; (iii) the effect of the evolutions of patients characteristics (age x gender, comorbidities). This decomposition approach is used in the litterature relative to the relationship between education and income distribution where observed distributions are compared to counterfactual distributions built by replacing some estimated parameters with their counterparts estimated from another country or period. Our results show that between 1994 and 1997 hospitals faced two main causes of rises in costs : on the one hand, diffusion of technological progress, with increasing use of costly innovative procedures such as angioplasty ; on the other hand, patients' epidemiological state worsened, since they became older and had more secondary diagnoses. These two factors induced sizeable shocks in cost distributions. During the same period, French public hospitals were financed by a global budget, and their budgets increased very slowly. However, international comparisons show that diffusion of technological progress for AMI treatment is similar in France and in comparable countries. How did French hospitals deal with their financial constraints ? Our results show that they sharply reduced the length of stays for patients at the bottom of the distribution. This reduction in the length of stays appears to have been a condition for the diffusion of angioplasty. Obviously, such a condition cannot be sustained in the long run without jeopardizing quality of care.

1 Introduction

This paper studies the relationship between the diffusion of innovative procedures and the evolutions of the cost and length of hospital stays. In contrast with macroeconomic evaluations, where the influence of technological progress is often reduced to a trend, microeconomic empirical evidence, from a sample of individual hospital stays, is used here. This allows us to use a direct information about the diffusion of technological progress and to evaluate the effects of technological progress on costs at different places of the costs distribution.

In the case of health care, direct information on technological progress diffusion can be gathered by observing changes in the use of innovative treatments and substitution between treatments. We focus on patients hospitalized with acute myocardial infarction. For these patients, the use of innovative procedures (such as angioplasty) is growing rapidly in all developed countries (TECH, (2001)). These procedures are less costly than more traditional ones (such as bypass surgery) and less invasive, i.e. more respectful of patients' quality of life. In some cases, innovative procedures can replace more traditional procedures. However, the use of innovative procedures is spreading in any case, independently of this type of substitution.

Performing such procedures requires investment in specific training and high-tech equipment. The process of diffusion of technological progress is thus composed of two steps : (i) adoption of new techniques by hospitals, (ii) an increase in the use of innovative procedures by hospitals which are able to perform them.

Diffusion of innovative procedures can have several effects on treatment costs. The implementation of the procedure can induce a direct increase in cost for each stay, plus an indirect increase due to the potential influence of the procedure on the stay duration. Diffusion of innovative procedures leads to a more frequent use and thus amplifies the increase in the average cost of heart attack treatment. However, an innovative procedure such as angioplasty can reduce treatment cost when it replaces a traditional procedure such as bypass surgery.

Our data covers public and private not-for-profit hospitals in France. We have a database with three dimensions (stays-hospitals-years) at our disposal relative to 11,573 stays for acute myocardial infarction observed over the period 1994 to 1997. Concentrating our analysis on cross-sections relative to years 1994 and 1997, we finally used a sample of 5,681 stays.

3

The study entails three stages.

In the first stage, we use a descriptive approach to characterize the pace and patterns of diffusion of innovative procedures for treating heart attacks, as well as the main features of AMI patients.

In the second stage, we estimate a four equations model explaining, for one AMI-patient in a given year, the cost and the length of stay, the probability of being assigned to an innovative hospital (which has adopted the new techniques), and - conditional on the assignment to an innovative hospital- the probability of use of an innovative procedure. This model is estimated for the first and last years of our observation period, i.e. 1994 and 1997. The estimations allow us to evaluate the additional cost attributable to the use of an innovative procedure.

The purpose of the third stage is to evaluate the influence of diffusion of technological progress on the distribution of treatment costs and length of stays. The principle of our analysis is the following : we use the probability of implementation of an innovative procedure, estimated on the basis of the 1997 data, to simulate the cost and length of stays for patients observed in 1994. Comparison of the result with actually observed or predicted costs for 1994 will allow us to assess the impact of diffusion of technological progress on treatment costs. A similar computation can be carried out using patients observed in 1997 as a reference. More precisely, we use microsimulation techniques in order to highlight various effects on the shifts in the overall distributions of the costs and length of stays : (i) the effect of the adoption of new techniques by hospitals (*between* hospital diffusion) ; (ii) the effect of the diffusion of technological progress *within* hospitals ; (iii) the effect of the changes in patients characteristics (age x gender, comorbidities). This decomposition approach is used in the litterature relative to the relationship between education, development and income distribution (Juhn, Murphy and Pierce (1993), DiNardo, Fortin and Lemieux (1996), Bourguignon, Ferreira and Leite (2002)), where observed distributions are compared to counterfactual distributions built by replacing some estimated parameters with their counterparts estimated from another country or period .

2   Pace and patterns of innovative procedures diffusion

We have at our disposal a sample of 11,538 stays for acute myocardial infarction (AMI) observed in 44 French hospitals operating in the public sector over the period 1994-1997. In France, public

hospitals[1] account for most of the total admissions (2/3 of admissions for AMI). Our sample has been extracted from the PMSI[2] cost database. Classification of stays by Diagnosis Related Group (DRG) is performed on the basis of diagnoses and procedures implemented during the stay. In order to obtain a high degree of patient homogeneity in terms of pathologies, we selected patients aged at least 40 years with acute myocardial infraction (AMI) as the main diagnosis and grouped in the DRGs 178 (complicated AMI) and 179 (uncomplicated AMI). For the purpose of our empirical exercise, we restricted the sample to two cross-sections : 2,269 and 3,412 stays observed in 1994 and 1997.

2.1 The AMI treatment

Together with drug therapy (aspirin, beta blockers, etc.), AMI patients can receive various treatments such as thrombolytic drugs, cardiac catheterization (hereafter denoted as CATH) and percutaneous transluminal coronary angioplasty (PTCA). Catheterization is a specialized procedure used to view the blood flow to the heart in order to improve the diagnosis. Angioplasty (PTCA) appeared more recently than bypass surgery. It is an alternative, less invasive procedure for improving blood flow in a blocked artery. This procedure is costly : its implementation induces an additional cost for one stay which ranges between 30 % and 60 %. General statistics performed on the total sample of AMI patients show that most of angioplasty are grouped in DRGs 179 and 178. Bypass surgery is implemented for a very small proportion, less than 3 % of AMI patients.

2.2 Innovation incentives within the French regulation

In France, public hospitals represent approximately 75 percent of the acute care beds. The financial incentives are quite different in the private and public sectors (Jacobzone *and alii* (2002) and Milcent (2003)). Public hospitals are financed by a global budget and their doctors are salaried. A deterrent to public sector use of innovative procedures is the financing of supplies from a global budget, which makes it difficult for them to purchase expensive devices. The global budget system

---

[1] In France and in the present study, the term "public hospitals" stands for hospitals belonging to the public sector as well as most of the private-not-for-profit hospitals.

[2] PMSI stands for the *Programme de médicalisation des systèmes d'informations,* which collects information about hospital activity. Information about the cost of the stays is available only from a hospitals sub-sample called "Base nationale de coûts".

does not take costly procedures such as catheterization or angioplasty into account and therefore penalises the public innovative hospitals which use them. On the opposite, most private hospitals are financed on the basis of a fee-for-service system. Supplies such as stents are reimbursed ex-post in addition to the fee-for-service payment and physicians receive additional fees for performing these procedures.

However, these different incentives do not lead to very contrasted physician behaviors. Milcent (2003) observes that large or middle-sized hospitals of all types (private, private-not-for-profit and public) have comparable significant rates of use of innovative procedures.

This can be interpreted by the existence of many indirect financial or non financial incentives for physicians working in the public sector. In teaching hospitals, physicians are involved in the international competition for research. Their career depends partly on their success in scientific publications. In addition, the allocation of the budget relies also on the hospital's reputation.

2.3 Basic features of the data

Our sample concerns stays observed in French public hospitals. These hospitals are regulated by a global budget system, with an increase in budgets close to zero in real terms during the period 1994-1997 that we study.

Table 1 reports statistics computed for the first (1994) and last (1997) year of our observation period. Indeed, our empirical study focuses on changes between these two years.

Most of the patients are men. The average age of the patients is the same in 1994 and 1997 : 67 years. A characteristic feature of heart disease is illustrated by figure 3 : young AMI patients are male ; the majority of AMI patients aged 75 and over are female. The proportions of male and female in age categories are quite similar in the years 1994 and 1997. Patients are slightly aging between these two years.

The epidemiological state of AMI patients is worsening : their number of secondary diagnosis is increasing rapidly (table 1). The proportion of patients with at least one non coronary secondary diagnosis is increasing, as well as the proportion of patients with at least one coronary secondary diagnosis. Figures 1 and 2 show the increase in the frequency of some particular secondary diagnoses :

arrhythmia, hypertension, heart failure, cerebrovascular disease and peripheral arterial disease[3].

Our indicator of the use of innovative procedures is the proportion of patients treated by an angioplasty. The table shows that the overall rate of use of this innovative procedure is growing rapidly in France : it went from 4.8 % of stays in 1994 to 15.6 % in 1997. More general statistics, computed on a larger sample of AMI patients and not reported here, show that angioplasty can replace more traditional procedures such as bypass surgery. However, this substitution effect explains only a small part of the increase in treatments by angioplasty.

Performing innovative procedures requires investment in specific training and high-tech equipment. The process of diffusion of technological progress is thus composed of two steps : first, the adoption of new techniques by hospitals ; second, the increase in the use of innovative procedures by hospitals which are able to perform them. We call the first step *between hospitals diffusion.* The second step is linked to a process of learning by doing (Ho (2002)) : we call it *within hospitals diffusion.* Between and within diffusion[4] are illustrated by figure 4. The proportion of hospitals able to perform innovative procedures is increasing rapidly. The proportion of angioplasty implemented within innovative hospitals is growing even more rapidly. These patterns are comparable to the pace of technological progress diffusion observed in comparable developed countries (TECH, 2001).

Table 1 also gives some information about the average length (LOS) and cost (C) of the stay. The average length of stay does not seem to be influenced by the performance of an angioplasty and decreases sharply between 1994 and 1997. On the contrary, a stay is much more costly when an innovative procedure has been implemented. The average cost per stay increased slightly, from 4,361.7 Euros in 1994 to 4,611.2 Euros in 1997, i.e. an increase in nominal terms of 5.7 % between 1994 and 1997.

This illustrates the strength of the global budget constraint during this period, with an increase of the average budget close to zero in real terms. During the same time, we have observed (figure 4) that the pace of technological progress diffusion is sizeable. How did hospitals manage to increase the use of innovative procedure in the context of such a financial constraint ? What is the nature

---

[3] One should be cautious about the interpretation of such an increase in the secondary diagnoses. It is likely to be the sign of a real worsening of patients' state. However, it can also be influenced by changes in physicians' behavior towards a more systematic registration of diagnoses. These changes in registration behavior are encouraged by the perspective of hypothetical reform in hospital payment system.

[4] The hospitals able to perform innovative procedures are called "*innovative hospitals*" and denoted *IH*.

of the link between the decrease in the length of stay and the technological progress diffusion ?

3   The empirical approach

Our purpose is to implement microsimulation techniques in order to examine the influence of various effects on the shifts in the distributions of the costs and length of stays. Our empirical approach entails two steps : firstly, the specification and estimation of a model explaining the length and costs of stays, as well as the diffusion of innovative procedures ; secondly, the use of the estimates to simulate counterfactual distributions which make it possible to evaluate the impacts of technological progress diffusion and changes in patients' characteristics. In this section, we present the econometric specification (3.1) and the principles of our microsimulations (3.2).

3.1   Econometric specification

For the patient i and the year τ, we consider the following model :

$$IH_{i\tau} = \mathsf{I}_{IH_{i\tau}^* > 0} \ \text{ with } IH_{i\tau}^* = x_{i\tau}' B_\tau + \nu_{i\tau} \tag{1}$$

$$proc_{i\tau} = \mathsf{I}_{\mathrm{Pr}\,oc_{i\tau}^* > 0} \ \text{ with } proc_{i\tau}^* = x_{i\tau}' D_\tau + \mu_{i\tau} \ \text{if } IH_{i\tau}^* > 0 \tag{2}$$

$$Log(LOS_{i\tau}) = x_{i\tau}' d_\tau + IH_{i\tau} a_\tau + proc_{i\tau} p_\tau + c_\tau + \xi_{i\tau} \tag{3}$$

$$Log(C_{i\tau}) = x_{i\tau}' \delta_\tau + LOS_{i\tau} \theta_\tau + IH_{i\tau} \alpha_\tau + proc_{i\tau} \pi_\tau + \gamma_\tau + u_{i\tau} \tag{4}$$

This model has a recursive structure[5] and entails two assignment equations and two equations explaining respectively the length and the cost of the stay.

The first assignment equation (1) explains, for a given patient's demographical and epidemiological characteristics x', the assignment to an innovative hospital. IH is a dichotomic variable taking the value 1 if the patient is assigned to a hospital able to perform angioplasty. The second assignment equation (2) explains, conditional on assignment to an innovative hospital, the probability of being treated through the use of an angioplasty. $proc$ is a dichotomic variable taking the value 1 if the patient is treated by an angioplasty. Equation (3) explains the logarithm of the length of the

---

[5] One has : (1)⇒(2)⇒(3)⇒(4) .

stay by the patient's characteristics x', the potential assignment to an innovative hospital and the potential treatment by an angioplasty. Equation (4) explains the logarithm of the cost of the stay by the same explanatory variables and the length of the stay.

In order to analyse the changes in the distributions of the lengths of stays and costs between 1994 and 1997, we estimate this four-equation model on the two cross-sections corresponding to the years 1994 and 1997. Despite we adopt a parametric approach, our estimates are rather flexible. Indeed, all the coefficients are allowed to change between 1994 and 1997.

3.2 Analysing changes in the distributions of treatment costs and length of stays

We now denote by Λ_τ the overall distribution of $Log(LOS)$ at time τ and by Γ_τ the overall distribution of $Log(C)$ at time τ. These distributions can be expressed as vector functions of observable and unobservable patient's characteristics and of the parameters at date τ. In our study, τ is equal to 1994 or 1997, denoted by 0 or 1 for the sake of simplicity.

$$\Lambda_\tau = \Lambda \left\{ x'_{i\tau}, \varepsilon_{i\tau} \, ; (B_\tau, D_\tau, d_\tau, a_\tau, p_\tau, c_\tau) \right\}, \text{ where } \varepsilon_{i\tau} = (\nu_{i\tau}, \mu_{i\tau}, \xi_{i\tau}).$$

$$\Gamma_\tau = \Gamma \left\{ x'_{i\tau}, \epsilon_{i\tau} \, ; (B_\tau, D_\tau, d_\tau, a_\tau, p_\tau, c_\tau, \delta_\tau, \theta_\tau, \alpha_\tau, \pi_\tau, \gamma_\tau) \right\}, \text{ where } \epsilon_{i\tau} = (\nu_{i\tau}, \mu_{i\tau}, \xi_{i\tau}, u_{i\tau}).$$

These distributions are represented in graphs[6] 1 and 2. Their changes between 0 and 1, $\Lambda_1 - \Lambda_0$ and $\Gamma_1 - \Gamma_0$, are displayed in graphs 1a and 2a. They can be explained by several effects :

i) The effect of the growing adoption of new techniques by hospitals. This between hospital diffusion is linked to a change from B_0 to B_1 in the coefficients of (1). With given demographical and epidemiological characteristics, a patient has a higher probability of being assigned to an innovative hospital in year 1 than in year 0.

ii) The effects of the within hospital diffusion should result in a change from D_0 to D_1 in the coefficients of (2).

iii) The effect of changes in patients' demographical (age, gender) and epidemiological (secondary diagnoses) characteristics. This population effect is related to changes in the observable $(x'_{i\tau})$ and unobservable $(\varepsilon_{i\tau}, \epsilon_{i\tau})$ patient characteristics.

---

[6] The distributions reported in this paper are kernel density estimates displayed by the software Stata. We used the Epanechnikov as kernel function and the default value chosen by the software for the bandwidth. On the other hand, the differences in densities displayed in this paper have been smoothed using a program provided by Stata.

The effects of the between and within hospital diffusion of innovative procedures on the costs and lengths of stays is more or less important, depending on their direct and indirect influences, which are captured through the coefficients a_τ, p_τ, α_τ, π_τ and θ_τ in (3) and (4). Shifts in the overall distributions depend on the three effects mentionned above and on the changes in all these other coefficients. In particular, changes from π_0 to π_1 can be linked to the changes in supply prices.

Consider now the overall distributions Λ_0 and Γ_0 of the logarithms of the length of stays and of costs at time 0 :

$$\Lambda_0 = \Lambda \left\{ x'_{i0}, \varepsilon_{i0} \, ; (B_0, D_0, d_0, a_0, p_0, c_0) \right\} \tag{5}$$

$$\Gamma_0 = \Gamma \left\{ x'_{i0}, \epsilon_{i0} \, ; (B_0, D_0, d_0, a_0, p_0, c_0, \delta_0, \theta_0, \alpha_0, \pi_0, \gamma_0) \right\} \tag{6}$$

The effects defined above can be evaluated as follows :

1) Between hospital diffusion :

$$d\Lambda_{0.1(B)} = \Lambda_{0.1(B)} - \Lambda_0 \tag{7}$$

where Λ_0 is defined by (5) and $\Lambda_{0.1(B)}$ by :

$$\Lambda_{0.1(B)} = \Lambda \left\{ x'_{i0}, \varepsilon_{i0} \, ; (B_1, D_0, d_0, a_0, p_0, c_0) \right\} \tag{8}$$

2) Within and between hospital diffusion :

$$d\Lambda_{0.1(B.D)} = \Lambda_{0.1(B.D)} - \Lambda_0 \tag{9}$$

where $\Lambda_{0.1(B.D)}$ is defined by : $\Lambda_{0.1(B.D)} = \Lambda \left\{ x'_{i0}, \varepsilon_{i0} \, ; (B_1, D_1, d_0, a_0, p_0, c_0) \right\}$

One can evaluate in the same way these 2 effects on the overall distribution of costs Γ :

$d\Gamma_{0.1(B)} = \Gamma_{0.1(B)} - \Gamma_0$ and $d\Gamma_{0.1(B.D)} = \Gamma_{0.1(B.D)} - \Gamma_0$ where Γ_0 is defined by (6).

3) Finally, the distributions of length of stays and costs are also influenced by the patients' demographical and epidemiological characteristics. We want to decompose the population effect into what is due to the observable characteristics and what can be attributable to unobserved heterogeneity. As stated by Bourguignon *et al. (2001),* it is possible to simulate a change in the

10

distribution of unobservable characteristics through a rank-preserving transformation. When this distribution is assumed to be normal with zero mean, this transformation is equivalent to :

$$\varepsilon_{i,0.1} = \varepsilon_{i0}\frac{\sigma_1}{\sigma_0},\qquad(10)$$

where $\varepsilon_{i,0.1}$ is the rank-preserving transformation[7] of the distribution of ε_{i0} in the distribution observed at time 1. More exactly, it is the simulation of the unobserved heterogeneity of patient i , observed in year 0, if he or she were ill in year 1.

To evaluate the effects of changes in patients' unobserved heterogeneity, one can compute :

$$d\Lambda_{0.1(\varepsilon)} = \Lambda_{0.1(\varepsilon)} - \Lambda_0 \qquad(11)$$

with $\Lambda_{0.1(\varepsilon)}$ defined by :

$$\Lambda_{0.1(\varepsilon)} = \Lambda\left\{x'_{i0}, \varepsilon_{i,0.1}\,;(B_0, D_0, d_0, a_0, p_0, c_0)\right\} \qquad(12)$$

To evaluate now the additional effect of changes in observable characteristics, we have to consider other individuals observed in year 1 :

$$d\Lambda_{0.1(x.\varepsilon)} = \Lambda_{0.1(x.\varepsilon)} - \Lambda_0 \qquad(13)$$

with $\Lambda_{0.1(x.\varepsilon)}$ defined by :

$$\Lambda_{0.1(x.\varepsilon)} = \Lambda\left[x'_{j1}, \varepsilon_{j,1}\,;(B_0, D_0, d_0, a_0, p_0, c_0)\right] \qquad(14)$$

The same reasoning is applied to evaluate the effects on the cost distribution of changes in patient observable characteristics and unobserved heterogeneity.

Let us briefly comment the principle of our computations. As concerns for instance the between and within diffusion effects, we compare the observed distribution at date 0 with an hypothetical

---

[7]More generally, a rank-preserving transformation of the distribution of ε_{i0} observed in 0 in the distribution ε_{i1} observed in 1 is given by : $\varepsilon_{i,0.1} = F_1^{-1}[F_0(\varepsilon_{i0})]$. Indeed, this leads to : $F_1(\varepsilon_{i,0.1}) = F_0(\varepsilon_{i0})$.

(counterfactual) distribution obtained by simulating on the patients observed at date 0 , the behaviors at date 1. These behaviors are characterized by the parameters B_1 (i.e. assignment to an innovative hospital) and D_1 (decision to treat with an innovative procedure). Given age, gender and secondary diagnoses, one has a higher probability of being treated by an angioplasty in year 1 than in 0. We try to evaluate the impact of this effect on the costs and length of stays distributions. Given the number of parameters of the four-equation model, one could simulate a very high number of combinations for the various possible effects. Considering them exhaustively seemed to us of low interest. We thus preferred to focus on the effects detailed above and then try to answer to questions of specific interest.

As stated by DiNardo *et alii* (1996) and Bourguignon *et alii* (2002), this approach can be seen as an extension of the Blinder-Oaxaca methodology to decompose the effects of discrimination between two groups of individuals into differences in mean income due to different mean characteristics of individuals in the two groups (here, our patients' characteristics) and differences in how these characteristics are remunerated within each group (here, the changes in parameters : how the same epidemiological characteristics can lead to a higher use of innovative procedures in year 1 than in year 0). The main change in our approach is that the decomposition is made on the full distribution rather than on means. Indeed, since the innovative procedures are not performed to treat every AMI patient, this diffusion of technological progress is likely not to affect the cost in the same way at each place of the distribution.

This kind of decomposition can be dependent on the year taken as reference. Therefore, we will compute, for the different effects, the evolutions $d\Lambda_{1.0(.)}$ and $d\Gamma_{1.0(.)}$, in order to check for the robustness of the results.

4 Results

In this section we first present the estimates of the four-equation model. Then, we use the results of our estimates to compute decompositions on means of the overall changes observed between 1994 and 1997. Overall average changes are splitted into changes due to shifts in coefficients and changes due to shifts in patient observable characteristics. This allows us to raise questions adressed in the analysis of distributions performed in the last subsections, devoted to the impact of technological

progress diffusion and of changes in patients' characteristics.

4.1 Econometric estimates

The recursive model defined by (1) to (4) has been estimated equation by equation for the years 1994 and 1997. A simple probit estimator has been used for equation (1), which explains assignment to an innovative hospital. Equation (2) explains, conditional on this assignment, the probability of being treated by an angioplasty. It has been estimated by a probit estimator with selection[8]. For identification purpose, the selection equation entails additional regressors[9] to the explanatory variables of (2). Denoting ρ the correlation coefficient between the perturbations of the probit equation and the selection equation of (2), the LR test leads us not to reject $\rho = 0$ for the year 1994, but to reject $\rho = 0$ in 1997 (5%).

The estimates[10] of (1) and (2) reveal that age has a significant negative influence on the probability of being assigned to an innovative hospital and on the probability of being treated with an innovative procedure. We notice a sharp rise in the constants of the two equations between 1994 and 1997. In addition, the influence of having a non coronary secondary diagnosis on the assignment to an innovative hospital increases significantly between these two years. These results illustrate the rapid between and within hospital diffusion of technological progress.

Table 2 gives in more details the results of the estimations of (3) and (4). We performed Hausman's tests to check for the exogeneity of the length of stay and of the dichotomous variables IH and $proc$ describing assignment to an innovative hospital and treatment by an angioplasty. The exogeneity of the length of stay being rejected in the cost equation for both years 1994 and 1997, this variable has been instrumented[11], as well as the variable $proc$, which appeared not to be exogenous for the year 1997.

There is an average decrease in the length of the stay which is indicated by the change in the constant : - 22.5 %, for the reference patient, a male aged 40-65, with no secondary diagnosis, who is not in an innovative hospital and has not been treated by an angioplasty. The explanatory

---

[8] First considered by Van de Ven and Van Pragg (1981).

[9] Detailed indicators of secondary diagnosis, hospital size, cross effects of patient's age and gender.

[10] Not reported here, available on request.

[11] For identification purposes, we had to consider instruments in addition to the explanatory variables of (3) in the structural model : we thus included age squared, age raised to the third power and several detailed indicators of secondary diagnosis (which are described in figures 1 and 2). These instruments are used for the estimation of (4) and to perform the exogeneity test.

variables of (3) and (4) relative to patients characteristics x' include cross effects of patient's gender and age (four levels) and two dichotomic variables indicating whether the patient has at least one non coronary secondary diagnosis and/or at least one coronary secondary diagnosis. We do not report the estimates concerning the coefficients of the cross effects of gender and age : they are all significant in equation (3) and show that the length of stay increases with age and is higher for women at all ages. These effects all increase between 1994 and 1997, indicating that the decrease in the length of stays, revealed by the change in the constant, is not homogenous for all patients.

Being assigned to an innovative hospital has a significant influence on the length of the stay (Table 2). This influence is positive in 1994, but becomes negative in 1997. This result, which may seem surprising, is understandable in the French context of the global budget system. During the period 1994-1997 covered by our study, budgets increased rather slowly and had no direct link to the actual production of hospitals. In that context, one way to extend the use of innovative (and costly) procedures was for an establishment to reduce the length of stays as much as possible. In any case, we observe that this behavior concerns all patients treated in an innovative hospital : for a given stay, the performance of an angioplasty does not significantly influence the length of the stay.

Another noteworthy result is the positive and significant influence of secondary diagnoses on the length of the stay. By contrast, secondary diagnoses appear to have no significant direct influence on the cost of the stay (see the two last columns of table 2). However, the length of the stay has a significant influence on costs, with a coefficient[12] of about 0.9. Therefore we can deduce that the secundary diagnoses have an indirect influence on costs, through the length of stays.

Costs are significantly higher in innovative hospitals. In 1994, they are 27.8 % higher. The estimated difference drops to 17.4 % in 1997. We find also that performing an angioplasty significantly increases the cost of a stay : + 30.1 % in 1994. The corresponding coefficient is 38.9 % in 1997[13]. This increase may be linked to changes in the technology of angioplasty (introduction of stents) and changes in supply prices.

To sum up, age and secundary diagnoses have a positive effect on the length of stay, which, in

---

[12] which does not change much between 1994 and 1997.

[13] This last coefficient appears to be not significant. However, we lost much of the variability of *proc* since we had to use its predicted values to deal with the outcome of the Hausman test.

turn, influences positively the cost of a stay. Costs are significantly higher in innovative hospitals and when an angioplasty has been performed. Our descriptive analysis has shown that the patients' state is worsening and that the use of innovative procedures is increasing rapidly, as well as the proportion of innovative hospitals. Therefore, the cost of the stay is likely to be subject to strong positive shocks. Our purpose is to study, within this context, the effect of the cost-containment induced by the global budget constraint on the distributions of the cost and of the length of stay.

4.2 First decomposition of overall changes between 1994 and 1997

We first consider decompositions on means of the overall changes between 1994 and 1997, in the spirit of the Oaxaca (1973) decomposition. For the sake of simplicity, we refer to the notation of a linear model (such as the length of stay and cost equations (3) and (4)). One has :

$$Y_{i0} = X_{i0}\beta_0 + u_{i0} \quad \text{and} \quad Y_{j1} = X_{j1}\beta_1 + u_{j1},$$

where i and j are relative to patients observed, respectively, in years 0 and 1. In general, there is no reason for the same patient to be observed in the two years. X_{i0} and X_{j1} are horizontal vectors of the observations of explanatory variables for patients i and j, respectively. Denoting by $Y_{.0}, Y_{.1}, X_{.0}, X_{.1}$ the sample means of the corresponding variables, and by $\hat{\beta}_0$ and $\hat{\beta}_1$ the estimated coefficients, we can compute the following decomposition :

$$Y_{.1} - Y_{.0} = X_{.0}\,(\hat{\beta}_1 - \hat{\beta}_0) + (X_{.1} - X_{.0})\,\hat{\beta}_1 \tag{15}$$

The first part of the right-hand side is the average change in Y due to shifts in the coefficients β. The second part is the change in Y due to the average shift in patients' observable characteristics X.

This decomposition takes the year 0 as the reference for the variables X. Choosing the year 1 as the reference for X leads to another decomposition : $Y_{.1} - Y_{.0} = X_{.1}(\hat{\beta}_1 - \hat{\beta}_0) + (X_{.1} - X_{.0})\hat{\beta}_0$. The result of this last computation can be different but should be close to the result of (15).

We use the estimates of equations (1) to (4) to compute the decompositions defined on means by (15). These are reported in table 3.

They show that the rise in the average probability of being assigned to an innovative hospital (+ 6.8 %) is due to shifts in coefficients (+ 2.8 %) and to changes in patient characteristics (+ 4.0 %). By constrast, the dramatic increase (+ 32 %) in the use of angioplasty within innovative hospitals is entirely due to changes in practices.

Changes in behavior induce a very sharp decrease in the length of stays (- 31.2 %), which is only slightly compensated by shifts in the explanatory variables (+ 6.55 %). The fact that changes in the explanatory variables tend to lengthen stays is mainly due to the secondary diagnoses : they have a positive influence on the length of stays and their frequency is rising between 1994 and 1997. However, the overall change in the length of the stays is strongly negative (-24.7 %) since it is widely dominated by the impact of changes in behaviors, which tend to shorten stays.

Finally, we notice that the average increase in cost per stay is rather small : + 5 % only, for nominal cost. This illustrates the strength of the global budget constraint during this period. How did hospitals deal with this financial constraint ? The decomposition of table 3 shows that changes due to shifts in explanatory variables are positive (+ 7.9 %) whereas changes dues to shifts in coefficients are negative (- 2.9 %). Apparently, hospitals tried to compensate for the extra costs arising from the increasing use of angioplasty by changing their behavior.

However, the interpretation of such a decomposition calls for a more thorough analysis. Firstly, changes in the explanatory variables of costs follow very different patterns between 1994 and 1997 : the length of stays decreases sharply ; the probability of being assigned to an innovative hospital rises ; the probability of being treated by an angioplasty rises. Secondly, the empirical exercice that we carry out in the decomposition of table 3 is rather limited. Indeed, the expression (15) is limited to one equation and assumes that there is a radical separation between changes in coefficients and changes in variables. In a more rigorous approach, one has to take into account the full information arising from the structural four-equation model. In this case, changes in the *coefficients* of, say, (1) and (2) induce changes in endogenous *variables* such as the length of stay in (4). This "full-information" approach is applied in the next subsection.

Notice, before, that we could extend the principle of decompositions on means to a similar analysis of the changes in distributions. Denote $d(Y_{i0})$ and $d(Y_{j1})$ the distributions of variables Y_{i0}

and Y_{j1}, $i = 1, ..., I$, $j = 1, ..., J$. One has, along the same reasoning as (15) :

$$d(Y_{j1}) - d(Y_{i0}) = \underbrace{d(X_{i0}\overset{\wedge}{\beta}_1 + \hat{u}_{i0})}_{} \overline{\underset{\{z}{}} \underbrace{d(X_{i0}\overset{\wedge}{\beta}_0 + \hat{u}_{i0})}_{\}} + \underbrace{d(X_{j1}\overset{\wedge}{\beta}_1 + \hat{u}_{j1})}_{} \overline{\underset{\{z}{}} \underbrace{d(X_{i0}\overset{\wedge}{\beta}_1 + \hat{u}_{i0})}_{\}} \qquad (16)$$

The resulting decompositions of the changes in distributions are illustrated by graphs 11 and 12 in the annex. However, it is more relevant to use a full information approach in order to identify the impact of technological progress diffusion on the distributions.

4.3   Analysing changes in the distributions of treatment costs and length of stays : the impact of technological progress diffusion

We now consider the approach defined in subsection 3.2. From the structural model defined by (1) to (4), we can express the distributions of $Log(LOS)$ and $Log(C)$ at time τ as vector functions of observable and unobservable patient's characteristics and of the parameters at date τ. The overall distribution Λ_0 of the logarithms of the length of stays at time 0 is defined by (5) : $\Lambda_0 = \Lambda\{x'_{i0}, \varepsilon_{i0} ; (B_0, D_0, d_0, a_0, p_0, c_0)\}$. To evaluate the impact of technological progress we want to measure two effects : firstly, the effect of the growing adoption of new techniques by hospitals ; secondly, the effects of the increasing use of angioplasty within hospital.

- The between hospital diffusion is linked to the change from B_0 to B_1 in the coefficients of (1). The results of our estimates revealed that this change if far from negligible. With given characteristics, a patient has a higher probability of being assigned to an innovative hospital in 1997 than in 1994. Using the estimates, we can simulate the counterfactual distribution (8) $\Lambda_{0.1(B)} = \Lambda\{x'_{i0}, \varepsilon_{i0} ; (B_1, D_0, d_0, a_0, p_0, c_0)\}$ and evaluate the effect of the between hospital diffusion on the distribution of the length of stay by (7) : $d\Lambda_{0.1(B)} = \Lambda_{0.1(B)} - \Lambda_0$.

- The within hospital diffusion is linked to the change from D_0 to D_1 in the coefficients of (2). We have seen that the growth in the use of angioplasty is very rapid and entirely due to a change in the coefficients of (2) : with given characteristics, the probability of being treated by an angioplasty is much higher in 1997 than in 1994. To evaluate the effect of the between and within hospital diffusion on the distribution of the length of the stay, we use the estimates to simulate the counterfactual distribution : $\Lambda_{0.1(B.D)} = \Lambda\{x'_{i0}, \varepsilon_{i0} ; (B_1, D_1, d_0, a_0, p_0, c_0)\}$. The difference in the

distributions is defined by (9) : $d\Lambda_{0.1(B.D)} = \Lambda_{0.1(B.D)} - \Lambda_0$.

The same reasoning applies to the analysis of the impact of between and within diffusion on the distribution Γ of the logarithms of the costs of the stays, with the distribution in year 0 defined by (6) : $\Gamma_0 = \Gamma\left\{x'_{i0}, \epsilon_{i0}\,; (B_0, D_0, d_0, a_0, p_0, c_0, \delta_0, \theta_0, \alpha_0, \pi_0, \gamma_0)\right\}$.

Graph 3 displays the distributions Λ_0, $\Lambda_{0.1(B)}$ and $\Lambda_{0.1(B.D)}$. Graphs 3a and 3b display, with the same scale, the differences $d\Lambda_{0.1(B)}$ and $d\Lambda_{0.1(B.D)}$, which make it possible to evaluate the effects of the between and within diffusion.

These effects appear to be rather small[14]. As concerns the within effect, this is not surprising : the performance of an angioplasty has no significant influence on the length of the stay (table 2). As for the between diffusion effect, it is rather surprising not to find a more sizeable effect, since the estimates revealed that being assigned to an innovative hospital has a significant positive influence on the length of the stay in 1994 : it is this coefficient which is used here to simulate the counterfactual distribution $\Lambda_{0.1(B)}$.

Turning now to the cost of the stays, graph 4 displays the distributions Γ_0, $\Gamma_{0.1(B)}$ and $\Gamma_{0.1(B.D)}$. Graphs 4a and 4b display, with the same scale, the differences $d\Gamma_{0.1(B)}$ and $d\Gamma_{0.1(B.D)}$, computed in order to evaluate the effects of the between and within diffusion.

Both effects appear to be quite sizeable. They induce an average rise in costs : the frequency of low-cost stay decreases whereas the frequency of expensive stays increases. The cumulated effects of between and within diffusion (graph 4b) is much larger than the between effect alone (graph 4a). It is worthwhile to notice that the positive shock on costs is limited to a specific place in the distribution[15].

4.4   Changes in the distributions : the impact of the worsening of patients' epidemiological state

The descriptive analysis of our data revealed that AMI patients are aging and that their epidemiological state is worsening : the number of secondary diagnoses increases rapidly. In addition, the estimates show that age and indicators of coronary and non coronary secondary diagnoses influence

---

[14] We use the same scale for these graphs and the graphs relative to the changes in patient characteristics, which induces a rather large scale for the impacts evaluated here.

[15] Such result gives empirical support to a regulation which would propose a lump-sum prospective payment for a stay associated with the performance of an angioplasty.

significantly the length of the stay (table 2).

To decompose the population effect into what is due to the observable characteristics and what can be attributable to unobserved heterogeneity, we simulate a change in the distribution of unobservable characteristics through the rank-preserving transformation defined by (10) : $\varepsilon_{i,0.1} = \varepsilon_{i0}\dfrac{\sigma_1}{\sigma_0}$, and compute (11) : $d\Lambda_{0.1(\varepsilon)} = \Lambda_{0.1(\varepsilon)} - \Lambda_0$, with $\Lambda_{0.1(\varepsilon)}$ defined by (12) : $\Lambda_{0.1(\varepsilon)} = \Lambda\left\{x'_{i0}, \varepsilon_{i,0.1}\,; (B_0, D_0, d_0, a_0, p_0, c_0)\right\}$.

To evaluate the additional effect of changes in observable characteristics, one has to consider other individuals observed in year 1 : $d\Lambda_{0.1(x.\varepsilon)} = \Lambda_{0.1(x.\varepsilon)} - \Lambda_0$, with $\Lambda_{0.1(x.\varepsilon)}$ defined by : $\Lambda_{0.1(x.\varepsilon)} = \Lambda\left(x'_{j1}, \varepsilon_{j,1}\,; (B_0, D_0, d_0, a_0, p_0, c_0)\right)$.

The same reasoning is applied to evaluate the effects on the cost distribution of changes in patients' observable characteristics and unobserved heterogeneity.

Graphs 5 displays the distributions of Λ_0, $\Lambda_{0.1(\varepsilon)}$ and $\Lambda_{0.1(x.\varepsilon)}$. Graphs 5a and 5b give, respectively, the differences : $d\Lambda_{0.1(\varepsilon)}$ and $d\Lambda_{0.1(x.\varepsilon)}$. Graph 5a shows that changes in unobservable heterogeneity result in more variability of the length of the stay. The change arising from shifts in patients' observable characteristics is quite sizeable (graph 5b). The worsening of the epidemiological state of patients in 1997, together with their aging, tend to lengthen hospital stays.

Graphs 6 displays the distributions of Γ_0, $\Gamma_{0.1(\varepsilon)}$ and $\Gamma_{0.1(x.\varepsilon)}$. Graphs 6a and 6b give, respectively, the differences : $d\Gamma_{0.1(\varepsilon)}$ and $d\Gamma_{0.1(x.\varepsilon)}$. The change arising from shifts in patients' observable characteristics is quite sizeable and results in an increase in the average cost per stay (graph 6b). Given the fact that age and secondary diagnoses are not significant in the cost equation, this effect results from an indirect influence of these variables through the length of stay, which is an explanatory variable of the cost (we have seen the sharp increase in the length of stays due to changes in patients' characteristics).

4.5   Changes in the distributions : the influence of shifts in LOS behavior

Our results show that between 1994 and 1997 hospital costs were subject to two positive shocks : diffusion of technological progress and worsening of patients' epidemiological state. Cumulating the effects of these two factors leads to a sizeable shock on cost distribution, which is much larger than the total change in cost distribution observed between 1994 and 1997 (compare graphs 3b and 5b

to graph 1a). In fact, the costs in the French public hospitals of our sample were limited by the global budget, which increased very slowly. In other words, French hospitals made it possible to provide a rapid diffusion of costly innovative procedures, despite two unfavorable conditions : cost containment and the worsening state of patients.

How did hospitals manage to increase their use of innovative procedures, despite the financial constraint induced by the global budget ? They reduced sharply their length of stay. Indeed, the most dramatic change that occured during the period was a change in the coefficients of the LOS equation between 1994 and 1997, which induced a tendency to shorten stays. More precisely, the results of the estimates (see subsection 4.1) show that there is a substantial reduction in the constant of equation (3) between 1994 and 1997 : -22.5 %. In addition, being assigned to an innovative hospital has a significant positive influence on the length of the stay in 1994, which becomes negative in 1997. The impact of this behavior changes on the distribution of length of stays is represented at the bottom of graph 7 (or in the appendix, graph 11a).

Graph 7 displays a synthesis of the changes in the LOS distribution and of the main shocks which affected this distribution between 1994 and 1997. We observe that the overall change is a tendency to shorten stays (graph 7a). The decomposition of this change into its main components show that (i) the impact of technological progress diffusion (graph 7b) is positive (lengthening of stays), but very small ; (ii) the impact of changes in patients characteristics is sizeable and tend to lengthen stays (graph 7c) ; taken together, these two effects are smaller than the very large impact of behavior change, represented in graph 7d. This last and negative effect widely dominate the impact of the worsening of the patients' state : on the whole, we observe a tendency to shorten stays.

This change in hospital behavior as regards length of stays induced cost savings. To evaluate these savings, we simulated the cost distribution in the year 1994, with the patients observed in 1994, but with the behavior estimated in 1997 as regards exclusively the length of stays. In other words, we simulated the following distribution[16] : $\Gamma_{0.1(LOS)} = \Gamma\left\{x'_{i0}, \epsilon_{i0} ; (B_0, D_0, d_1, a_1, p_1, c_1, \delta_0, \theta_0, \alpha_0, \pi_0, \gamma_0)\right\}$. The difference : $d\Gamma_{0.1(LOS)} = \Gamma_{0.1(LOS)} - \Gamma_0$ gives the savings in costs due to the changes in the

---

[16]Notice that d, a, p and c are the coefficients of the LOS equation.

coefficients of the length of the stay function. Graph 8 displays the distribution of Γ_0 and $\Gamma_{0.1(LOS)}$. Graph 8a gives the difference : $d\Gamma_{0.1(LOS)}$. These graphs reveal the magnitude of the cost savings induced by the change in LOS behavior.

Graph 9 displays a synthesis of the changes in the cost distribution and of the main shocks which affected this distribution between 1994 and 1997. The overall change is a rather limited rise in costs, linked to the small increase in global budgets (graph 9a). The decomposition of this change into its main components show that (i) the impact of technological progress diffusion (graph 9b) is positive and sizeable ; (ii) the impact of changes in patients characteristics is positive and even larger (graph 9c) ; the saving effect of shifts in the coefficients of the length of stay equation (graph 9d) is larger and widely compensates the effects on costs of the diffusion of innovative procedures (9b). On the whole, this last and negative effect partly dominates the cumulated impact of the technological progress diffusion (graph 9b) and of the worsening of the patients' state (graph 9c) : the overall rise in costs is limited.

How did the hospitals succeed in such a shortening of the length of stays ? Graph 10 allows us to examine more thoroughly the changes that occured on the LOS distribution. We have seen (graph 7) that this distribution was subject to two main shocks : the effect of the worsening state of patients and the effect of changes in behavior. The curves corresponding to these two effects are superimposed on graph 10, together with a vertical line which represents the first quartile of the length of stays in the year 1994. We notice that the effect of the shortening of the stays linked to the change in behavior takes place around the first quartile, i.e. more on the left of the distribution in comparison to the lengthening of stays due to changes in patient characteristics. This result suggests that hospitals concentrate their effort of reduction (and maybe, take some risks) on patients of the bottom of the distribution of the length of stay, which can be interpreted as patients without complications.

5   Conclusion

To sum up, between 1994 and 1997, hospitals faced two main causes of rises in costs : on the one hand, diffusion of technological progress, with increasing use of costly innovative procedures such as

angioplasty; on the other hand, patients' epidemiological state worsened, since they became older and had more secondary diagnoses. These two factors induced shocks in the cost distributions.

During the same period, French public hospitals were financed by a global budget, and their budgets increased very slowly. Hence, growth in overall average costs was limited by the rather slow rate of growth in global budgets. However, international comparisons show that diffusion of technological progress for AMI treatment is similar in France and in comparable countries (TECH (2001)). How did French hospitals deal with their financial constraints? Our results show that they sharply reduced the length of stays for patients at the bottom of the distribution. This reduction in the length of stays appears to have been a condition for the diffusion of angioplasty. Obviously, such a condition cannot be sustained in the long run without jeopardizing quality of care.

Regarding methodology, our study refers to Juhn, Murphy and Pierce (1993), DiNardo, Fortin and Lemieux (1996) and Bourguignon, Ferreira and Leite (2002)), all of whom focus on income distribution. In this paper, most observed changes are in means, not in spread. The main interest of our decompositions is that they reveal that the changes in means do not lie at the same place in the distribution, depending on the effect considered.

6   References

Bourguignon, F., Fournier M. and M. Gurgand M., (2001) "Fast development with a stable income distribution : Taiwan, 1975-1994", Review of Income and Wealth, 47(2), 139-63

Bourguignon, F., Ferreira, F. H. G. and Leite, P. G. (2002), "Beyond Oaxaca-Blinder : Accounting for Differences in Household Income Distribution Across Countries", Working paper Delta n°$2002-04$

DiNardo, J. , Fortin N. M. and Lemieux T. (1996) "Labor market institutions and the distribution of wages, 1973-1992 : a semiparametric approach", Econometrica, Vol. 64, n°5, pp 1001-1044.

Dormont B. and Milcent C. (2003), " How to Regulate Heterogenous Hospitals", Working Paper Thema, n° 2003-14

Ho V. (2002), "Learning and the evolution of medical technologies : the diffusion of coronary angioplasty", Journal of Health Economics, Vol. 21, pp 873-885

Jacobzone, S., Dormont, B. and Durand Zaleski, I., (2002), "Technological Change in Heart

Attack Care in France : Causes and Consequences." In *Technological Change in Health Care. A Global Analysis of Heart Attack,* Mark B. McClellan and Daniel B. Kessler Eds. The University of Michigan Press.

Juhn, C., Murphy, K. M. and Pierce, B. (1993), "Wage Inequality and the Rise in Returns to Skill", The Journal of Political Economy, Vol. 101, Issue 3 : pp 410-442.

Kesteloot, K. and Penninckx, F. (1993), "The costs and effects of open versus laparascopic cholecystectomies", Health Economics, vol 2 : pp 303-312

McClellan, M. et Newhouse, J. P. (1997), "The marginal cost-effectiveness of medical technology : A panel instrumental-variables approach", Journal of Econometrics, vol 77 : pp 39-64

Milcent C. (2003) " Ownership, System of reimbursement and Mortality rate relationships", Working Paper Delta, n° 2003.

Oaxaca, R. (1973) "Male-Female Wage Differentials in Urban Labor Markets", International Economic Review, 14, 693-709.

The Technological Change in Health Care (TECH) Research Network (2001). " Technological Change Around The World : Evidence From Heart Attack Care. ", Health Affairs.; 20(3) :25-42).

Van de Ven W. P. M. and Van Pragg B. M. S. (1981), " The demand for deductible in private health insurance : a probit model with sample selection". Journal of Econometrics*, 17 : 229-252.

Table 1: Basic features of the data

		1994	1997
Number of stays		2,269	3,412
Patient's characteristics	Gender (proportion of female)	29.7	31.2
	Average age (year)	67	67
	Number of secondary diagnoses (percentage):		
	None	26.6	10.6
	1-3	57.7	51.8
	Over 3	15.7	37.6
	At least one non coronary secondary diagnosis (percentage)	45.0	71.1
	At least one coronary secondary diagnosis (percentage)	59.1	70.7
	Angioplasty (percentage)	4.8	15.6
Length of stay	Average LOS (days) (Standard deviation)	11.6 (7.1)	9.7 (7.0)
	Stay without angioplasty (Standard deviation)	11.6 (7.1)	9.9 (7.0)
	Stay with angioplasty (Standard deviation)	11.8 (6.1)	8.5 (6.8)
Cost	Average cost (euros) (Standard deviation)	4,361.7 (2,980.0)	4,611.2 (3,088.9)
	Stay without angioplasty (Standard deviation)	4,252.7 (2,947.9)	4,334.5 (2,914.5)
	Stay with angioplasty (Standard deviation)	6,542.7 (2,784.8)	6,109.3 (3,546.9)

PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

Figure 1: Frequency of coronary secondary diagnoses
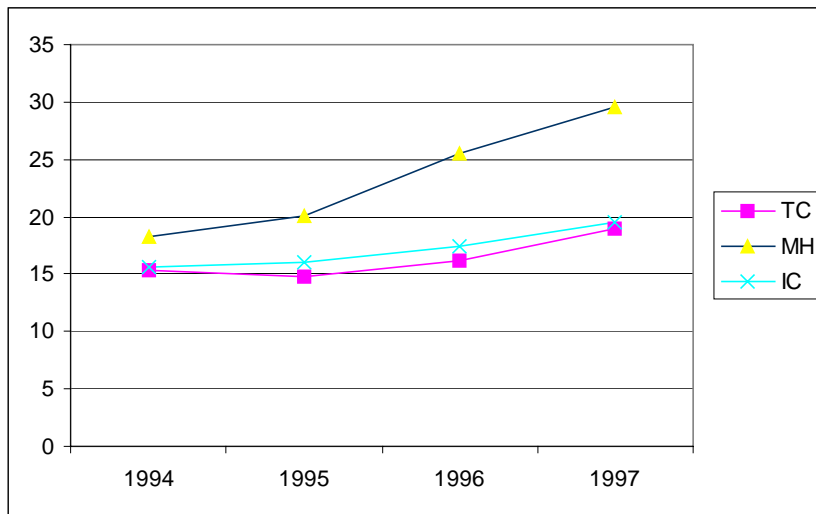
TC: arrhythmia
MH: hypertension
IC: heart failure

Figure 2: Frequency of other coronary secondary diagnoses
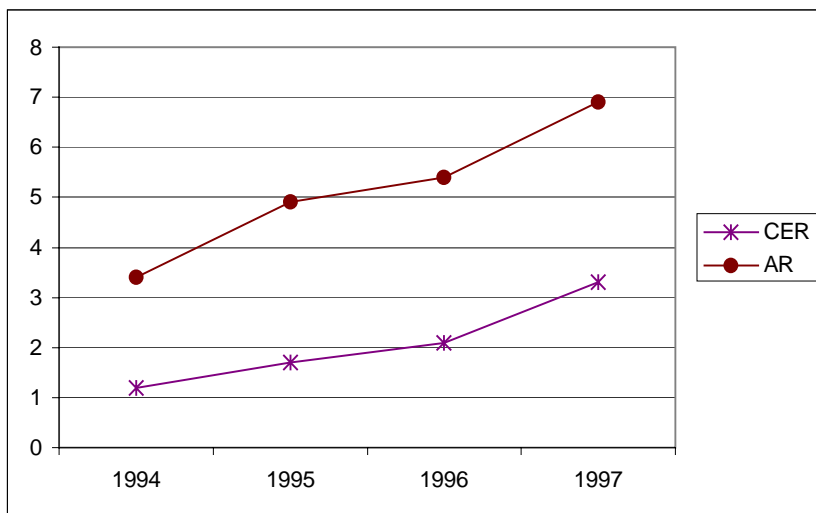
CER: cerebro-vascular disease
AR: peripheral arterial disease

Figure 3: Patients' characteristic. Age and gender
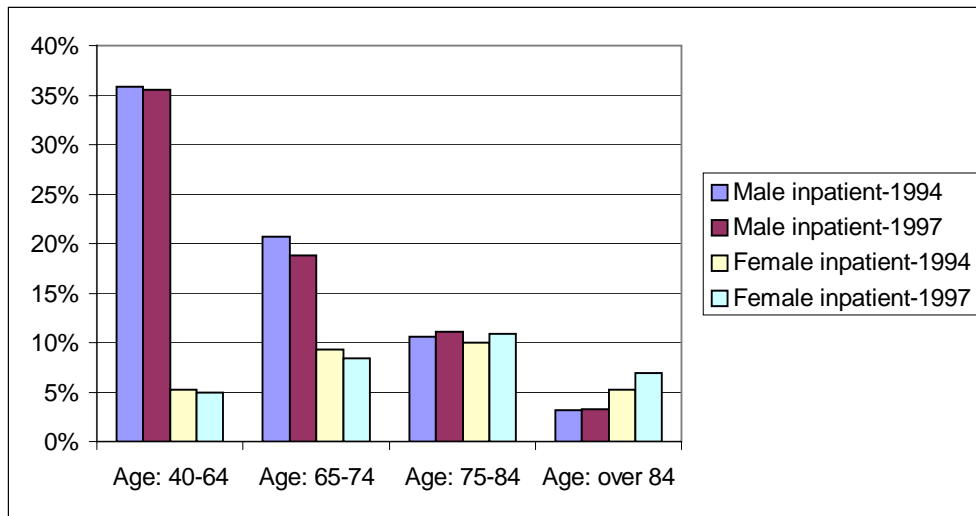
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

Figure 4: PTCA diffusion (Between and Within)
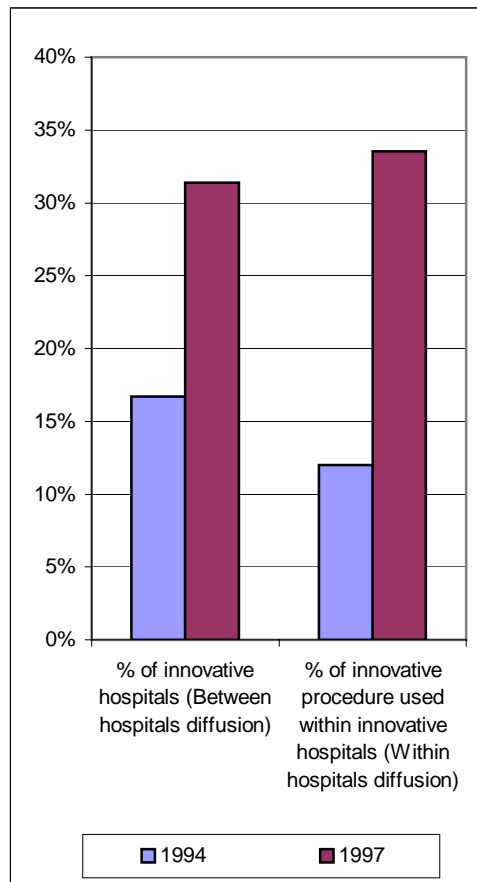
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

Graph 1: Distribution of the logarithm of the length of stay in 1994 (Λ_0) and 1997 (Λ_1)

PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997
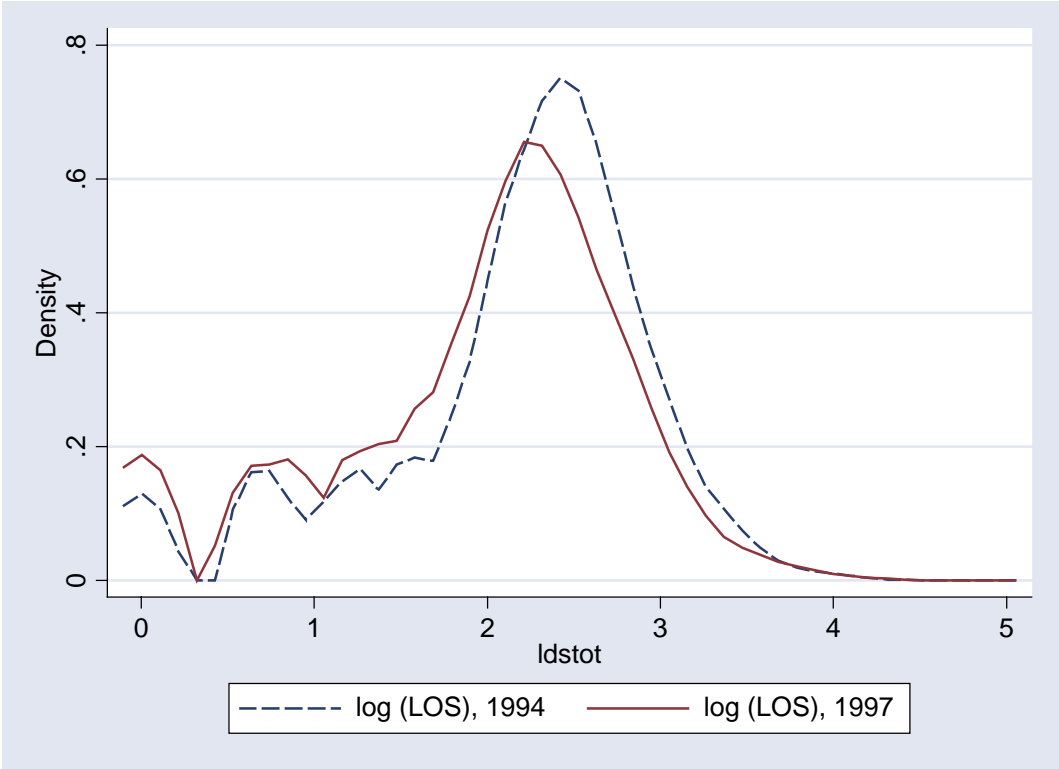
Graph 1a: Change in the distribution between 1994 and 1997 ($\Lambda_0 - \Lambda_1$)
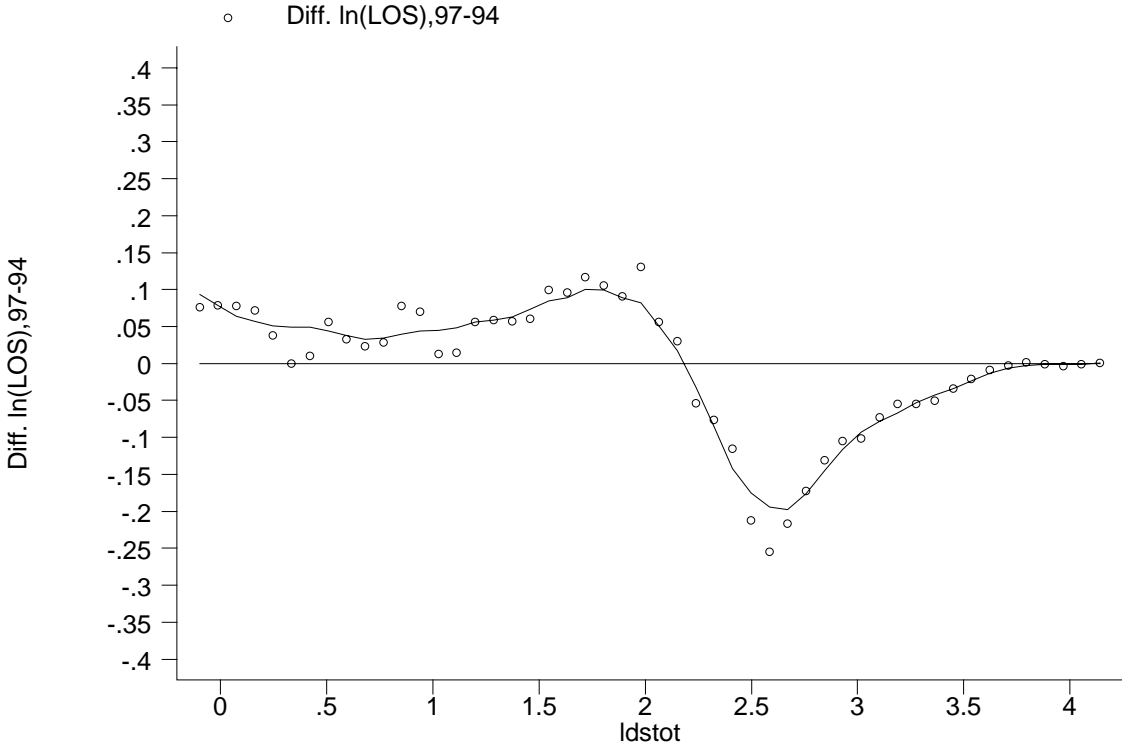
Graph 2: Distribution of the logarithm of the cost of stay in 1994 (Γ_0) and 1997 (Γ_1)
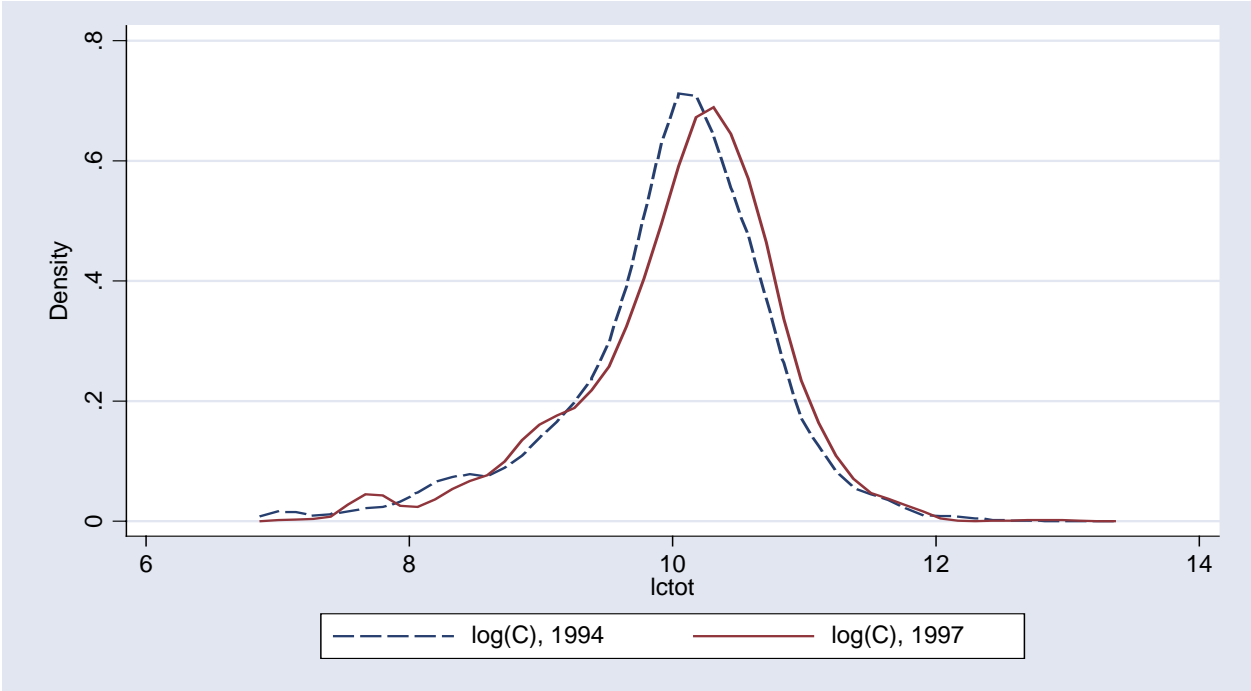
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

Graph 2a: Change in the distribution between 1994 and 1997 ($\Gamma_1 - \Gamma_0$)
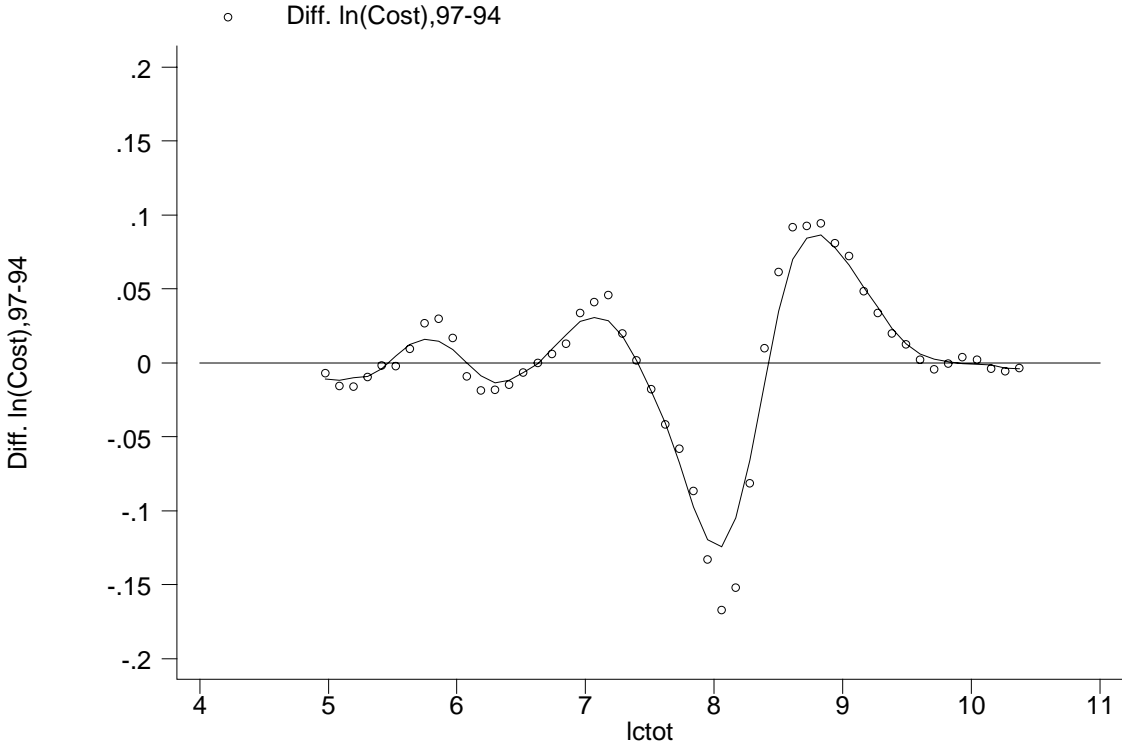
Table 2: Estimated coefficients for Equations (3) Length of stay and (4) Cost

	Log(LOS)		*Log(C)*	
	94	97	94	97
Non coronary secondary diagnosis	0.314** (0.029)	0.074** (0.029)	0.006 (0.050)	0.049 (0.034)
Coronary secondary diagnosis	0.163** (0.031)	0.332** (0.031)	0.052 (0.040)	0.044 (0.053)
Log(LOS) *Hausman Test for H_0 : exogeneity*	- -	- -	0.899** (0.136) H_0 rejected (0.036)	0.849** (0.096) H_0 rejected (0.001)
Innovative Hospital *Hausman Test for H_0 : exogeneity*	0.129** (0.031) H_0 non rejected (0.050)	-0.139** (0.032) H_0 non rejected (0.848)	0.278** (0.030) H_0 non rejected (0.437)	0.174** (0.024) H_0 non rejected (0.609)
Angioplasty *Hausman Test for H_0 : exogeneity*	-0.028 (0.061) H_0 non rejected (0.269)	-0.008 (0.047) H_0 non rejected (0.163)	0.301** (0.068) H_0 non rejected (0.103)	0.389 (0.429)[1] H_0 rejected (0.022)

**: The estimated coefficient is significant at 1 % level.

Models also included patient characteristics. When the Hausman's test leads to rejection of the null hypothesis, the corresponding variable is instrumented in the regression. In the present version of the paper we only computed the second step standard errors in those cases.

[1] Consistently estimated standard error by bootstrap (1000 replications)

Table 3: Overall changes between 1994 and 1997: first decomposition on means

Equation		Total changes 1994 – 1997 (%) (1)	Changes due to shifts in coefficients (2)	Changes due to shifts in explanatory variables (3)
(1)	Assignment to an innovative hospital	+ 6.8	+ 2.8 (+ 6.5)	+ 4.0 (+ 0.3)
(2)	Treatment by an angioplasty	+ 32.0	+ 32.0 (+ 27.0)	0.0 (+ 5.0)
(3)	Length of stay	- 24.7	- 31.2 (- 35.36)	+ 6.55 (+ 10.68)
(4)	Cost of stay	+ 5.0	- 2.9 (- 10.1)	+ 7.9 (+ 15.1)

The decompositions given here take the year 1994 as a reference for the explanatory variables. In parentheses are given the decompositions resulting from the other possible computation, which takes the year 1997 as a reference for the explanatory variables.

Graph 3: Distribution of ln(LOS) in 1994 and counterfactual distributions of ln(LOS) to evaluate the impact of technological progress diffusion
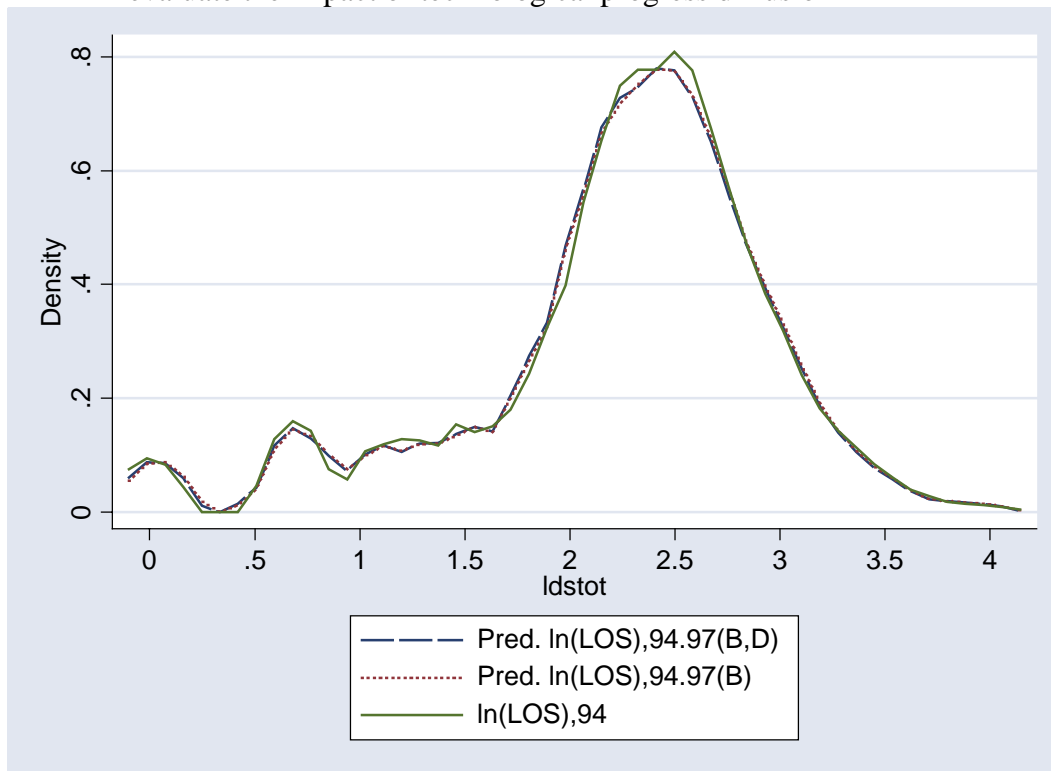
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

ln(LOS), 94: distribution of ln(LOS) observed in 1994

ln(LOS), 94. 97(B): counterfactual distribution of ln(LOS) in 1994 due to the rise in the number of innovative hospitals in 1997
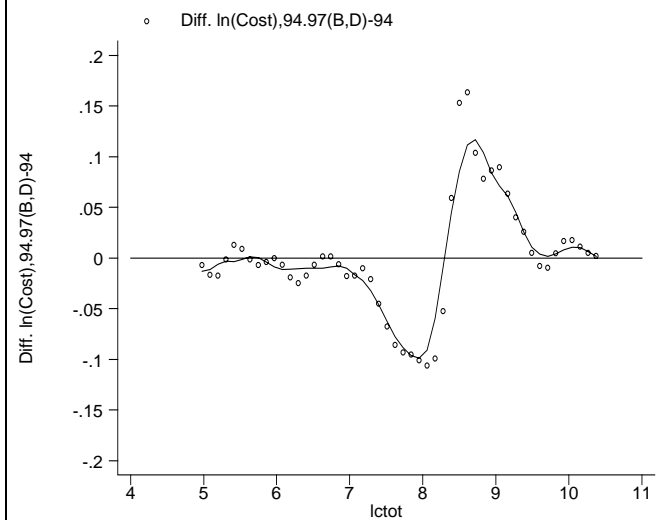
ln(LOS), 94. 97(B,D): counterfactual distribution of ln(LOS) in 1994 due to the rise in the number of innovative hospitals in 1997 and to the increase in the probability of angioplasty

Graph 3a: Effect of between hospital diffusion on the distribution of ln(LOS)
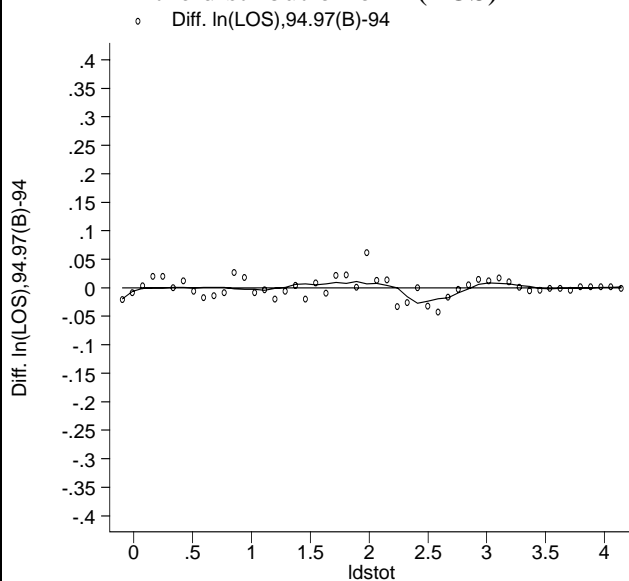
Difference between counterfactual distribution of ln(LOS) and distribution of ln(LOS), 94

Graph 3b: Cumulated effect of between and within diffusion of the distribution of ln(LOS)
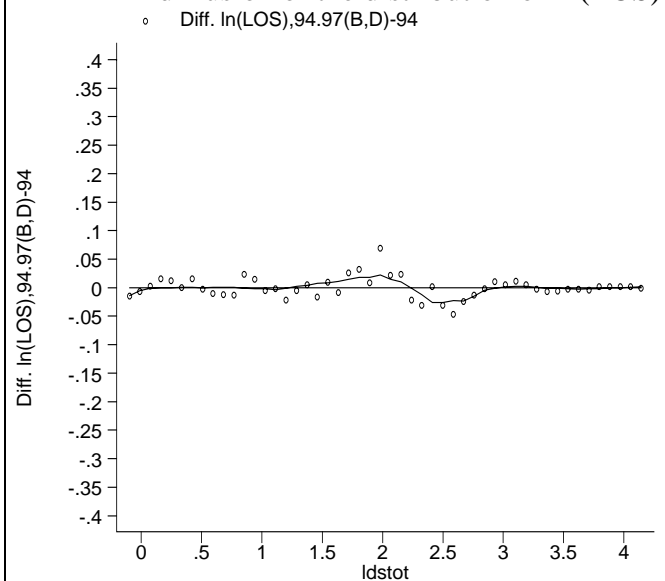
Difference between counterfactual distribution of ln(LOS) and distribution of ln(LOS), 94

Graph 4: Distribution of ln(cost) in 1994 and counterfactual distributions of ln(cost) to
evaluate the impact of technological progress diffusion
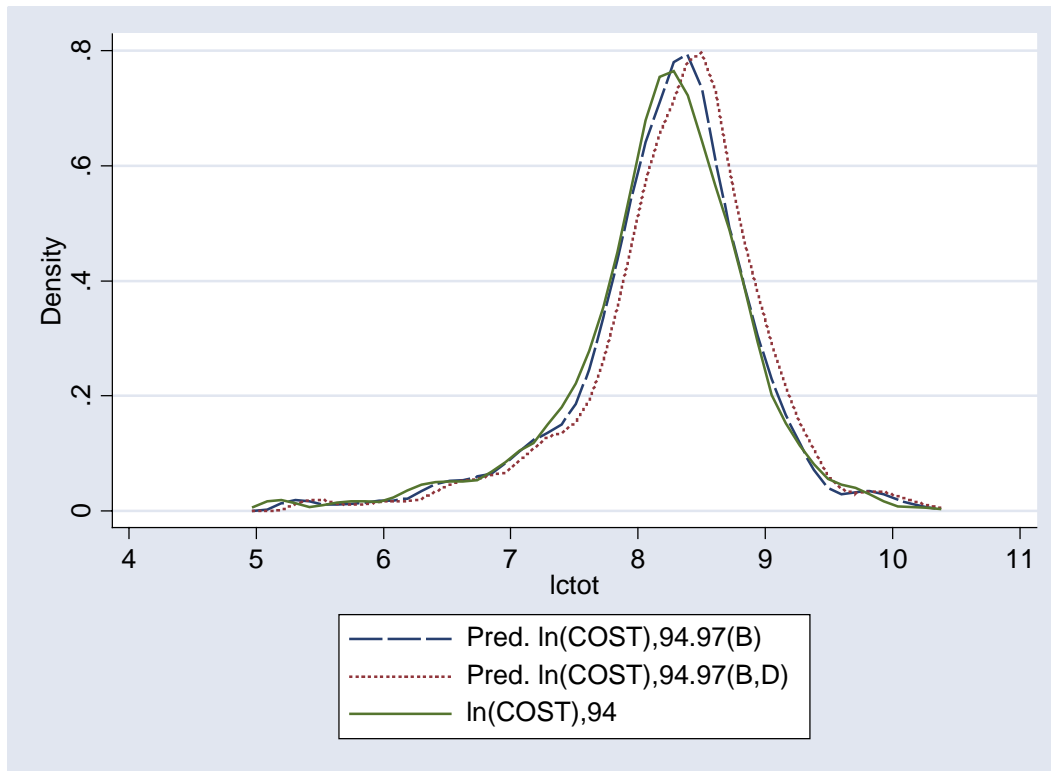
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

ln(cost), 94: distribution of ln(cost) observed in 1994

ln(cost), 94. 97(B): counterfactual distribution of the ln(cost) in 1994 due to the rise in the number of innovative
hospitals in 1997

ln(cost), 94. 97(B,D): counterfactual distribution of the ln(cost) in 1994 due to the rise in the number of
innovative hospitals in 1997 and to the increase in the probability of angioplasty

Graph 4a: Effect of between hospital diffusion on the distribution of ln(cost)	Graph 4b: Cumulated effect of between and within diffusion of the distribution of ln(cost)
Difference between counterfactual distribution of ln(cost) and distribution of ln(cost), 94	Difference between counterfactual distribution of ln(cost) and distribution of ln(cost), 94
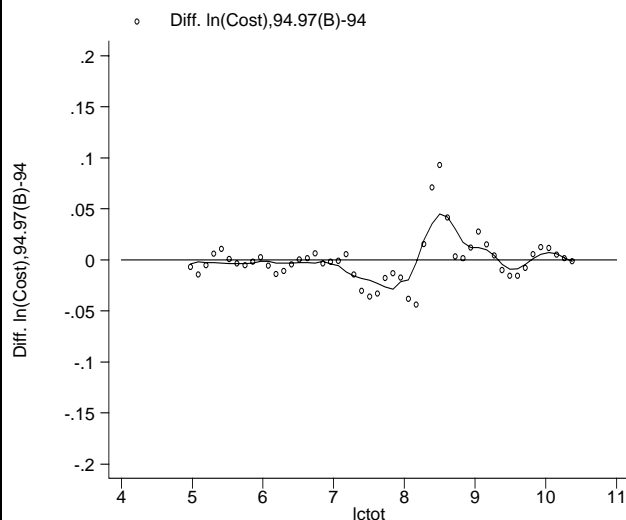
31

Graph 5: Distribution of ln(LOS) in 1994 and counterfactual distributions of ln(LOS) to evaluate the impact of changes in observable and unobservable patients' characteristics
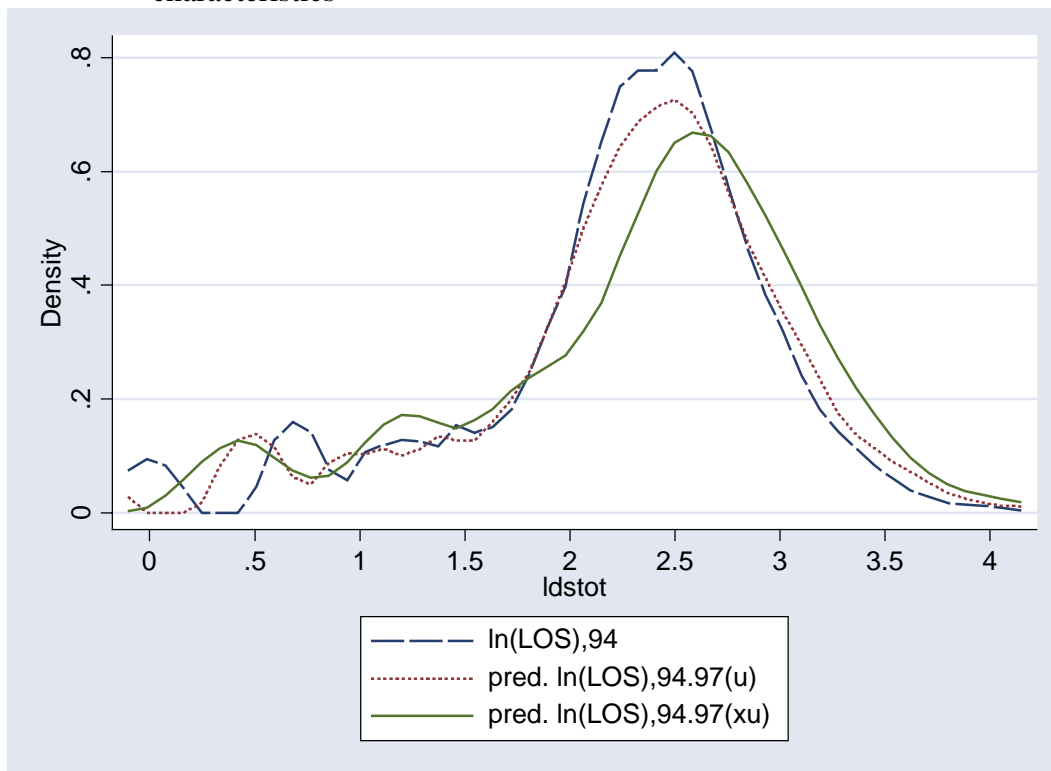
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997

Graph 5a: Effect of changes in unobservable heterogeneity on the distribution of ln(LOS)
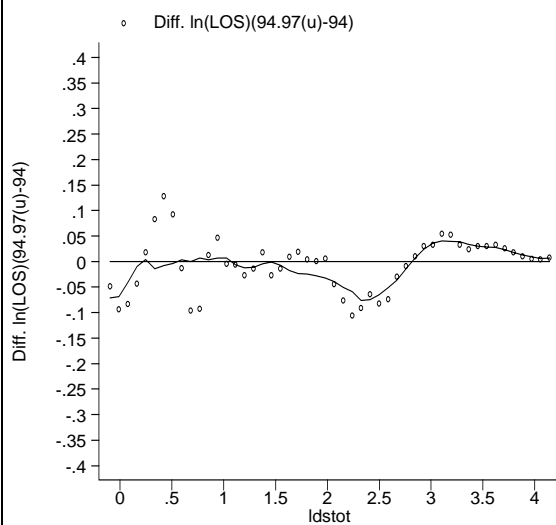
Graph 5b: Effect of changes in unobservable heterogeneity and observable patients' characteristics on the distribution of ln(LOS)
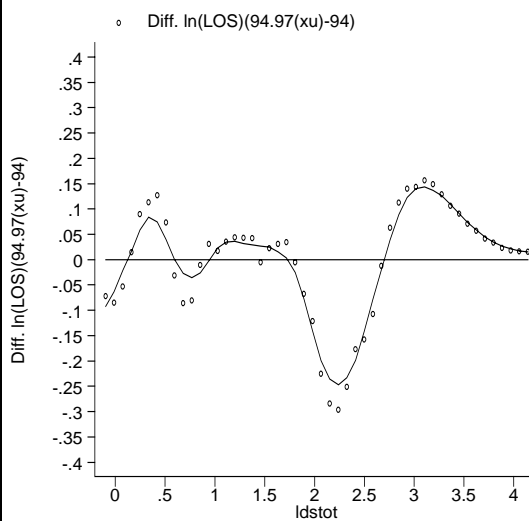
Graph 6: Distribution of ln(cost) in 1994 and counterfactual distributions of ln(cost) to
evaluate the impact of observable and unobservable patients' characteristics
change
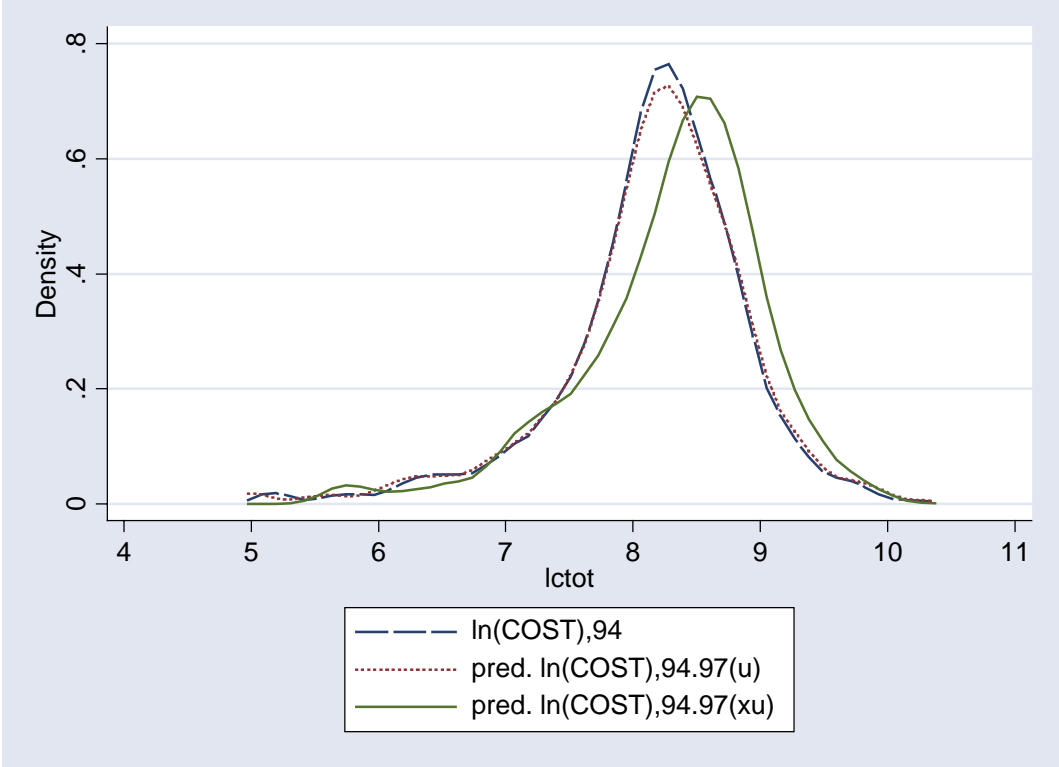
PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997
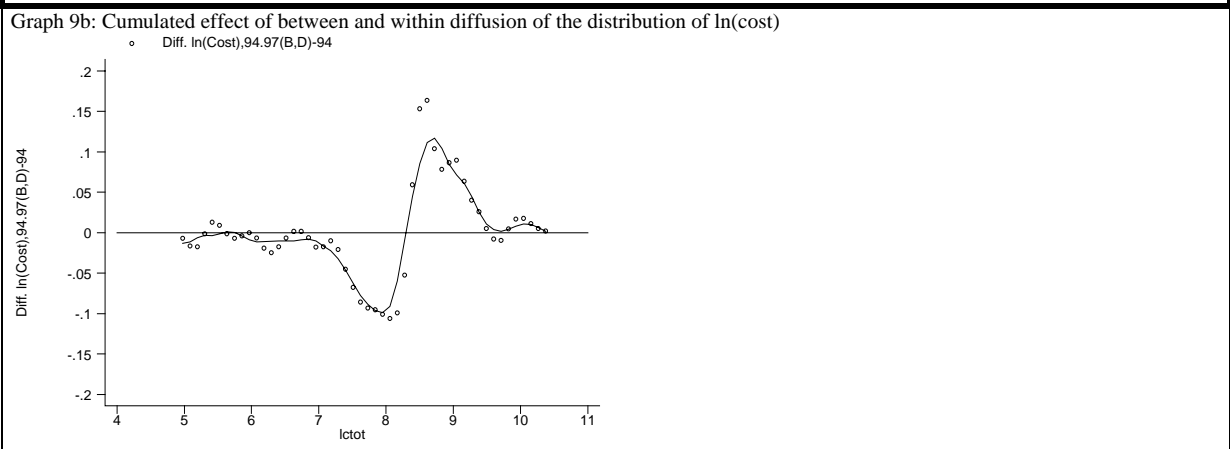
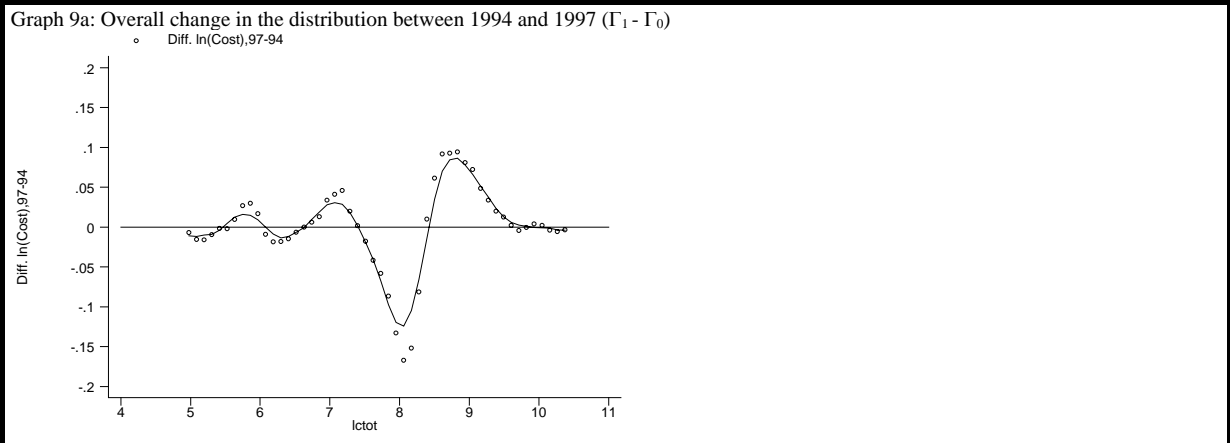

Graph 6a: Effect of changes in unobservable heterogeneity on the distribution of ln(cost)
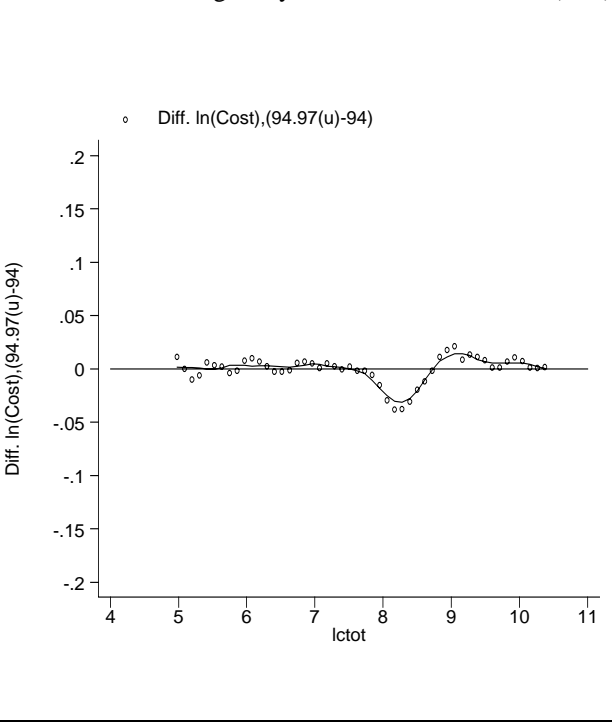
Graph 6b: Effect of changes in unobservable heterogeneity and observable patients' characteristics on the distribution of ln(cost)
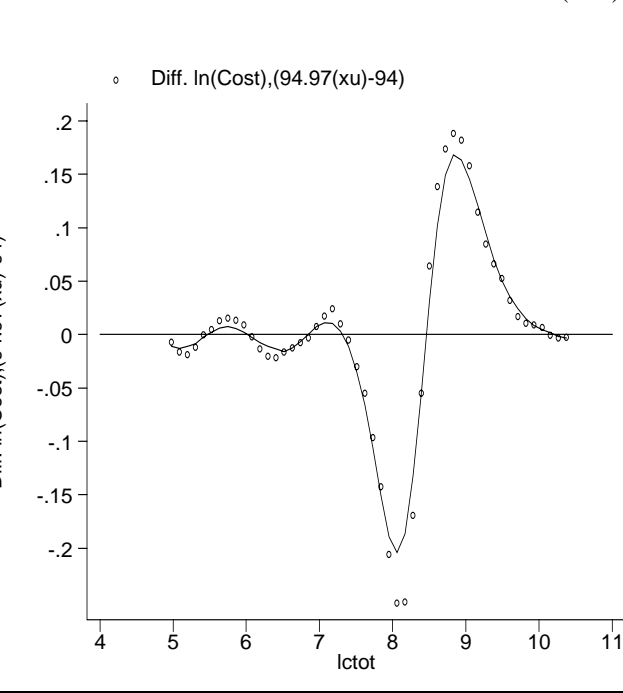
Graphs 7 : LOS distribution : overall change and main shocks between 1994
and 1997.

Graph 7a: Overall change in the distribution between 1994 and 1997 ($\Lambda_0 - \Lambda_1$)
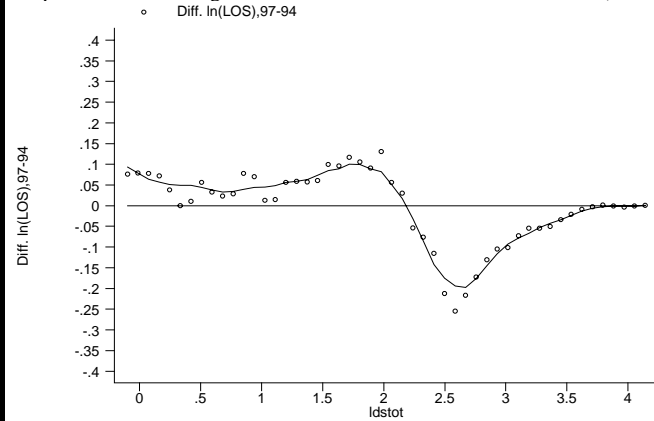
Graph 7b: Cumulated effect of between and within diffusion of the distribution of ln(LOS)
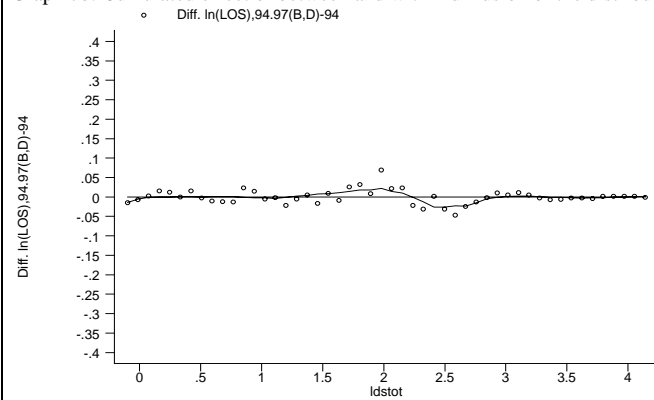
Graph 7c: Effect of changes in unobservable heterogeneity and observable patients' characteristics on the distribution of ln(LOS)
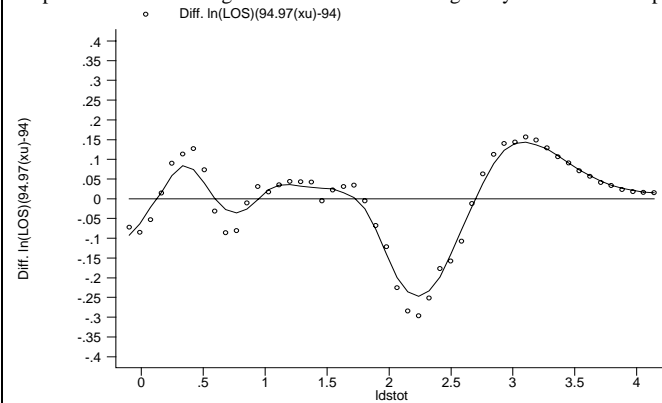
Graph 7d: Change in the distribution due to shifts in the coefficients $d(X_{i0}\beta_1+u_{i0}) - d(X_{i0}\beta_0+u_{i0})$
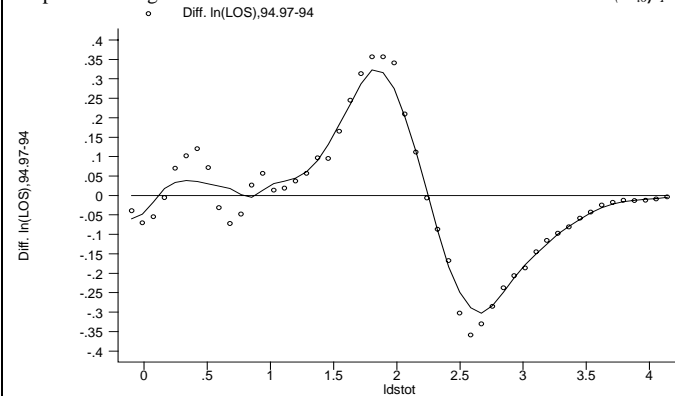
Graph 8: Distribution of ln(cost) in 1994 and counterfactual distribution of ln(cost) to evaluate
the impact of changes in the LOS behavior between 1994 and 1997
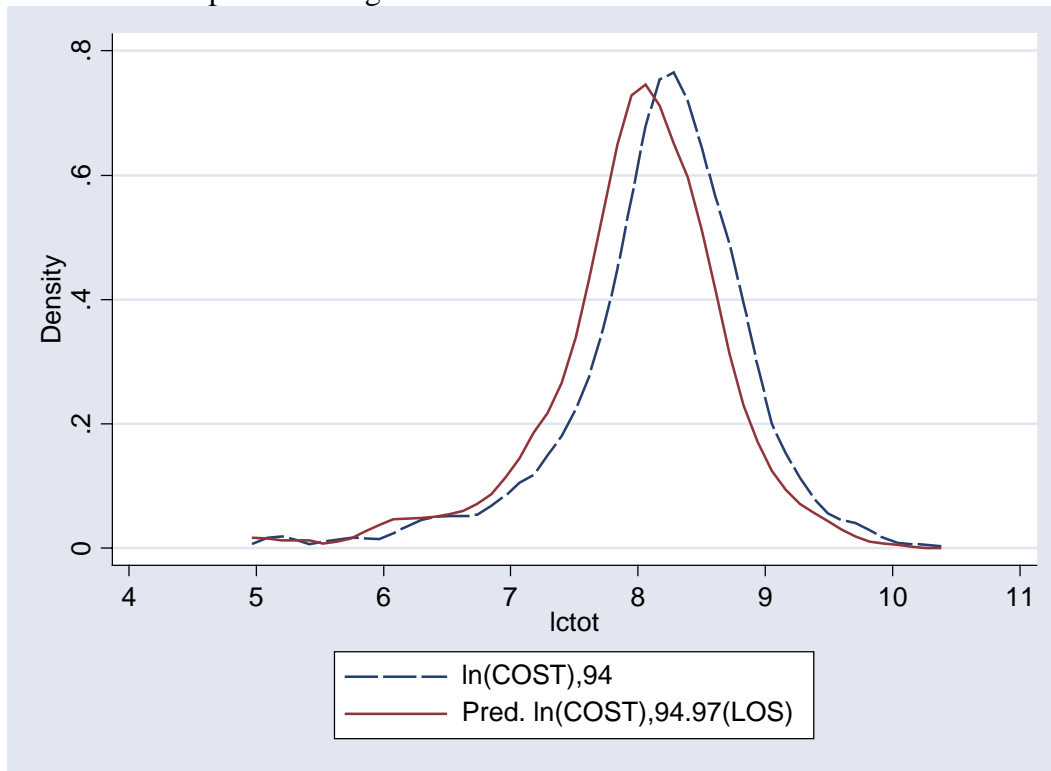
ln(cost), 94: distribution of ln(cost) observed in 1994

pred. ln(cost)94.97(LOS): counterfactual distribution of ln(cost) with patients observed in 1994 and
coefficients of 1997 for the prediction of LOS exclusively

Graph 8a: Savings in cost due to changes in the LOS behavior between 1994 and 1997
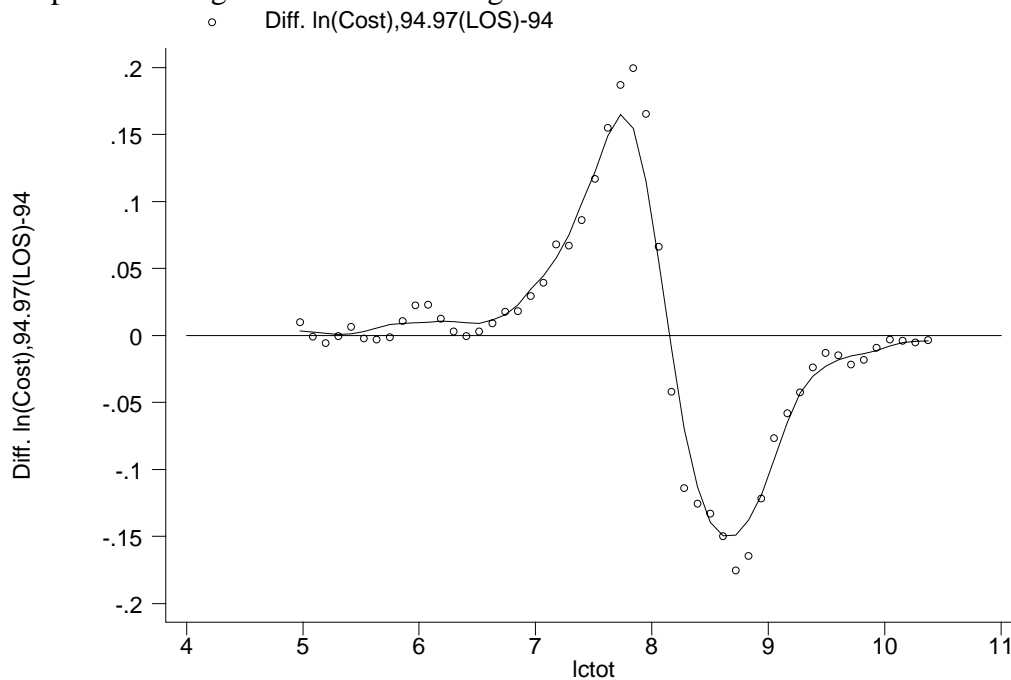
Graphs 9 : Costs distribution : overall change and main shocks between 1994 and 1997.

Graph 9a: Overall change in the distribution between 1994 and 1997 ($\Gamma_1 - \Gamma_0$)

Graph 9b: Cumulated effect of between and within diffusion of the distribution of ln(cost)

Graph 9c: Effect of changes in unobservable heterogeneity and observable patients' characteristics on the distribution of ln(cost)

Graph 9d: Savings in cost due to changes in the LOS behavior between 1994 and 1997
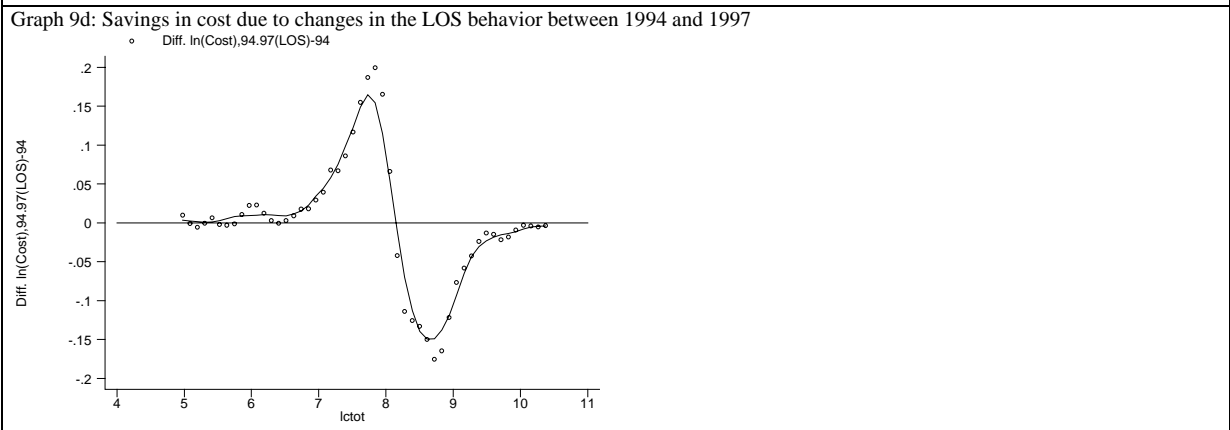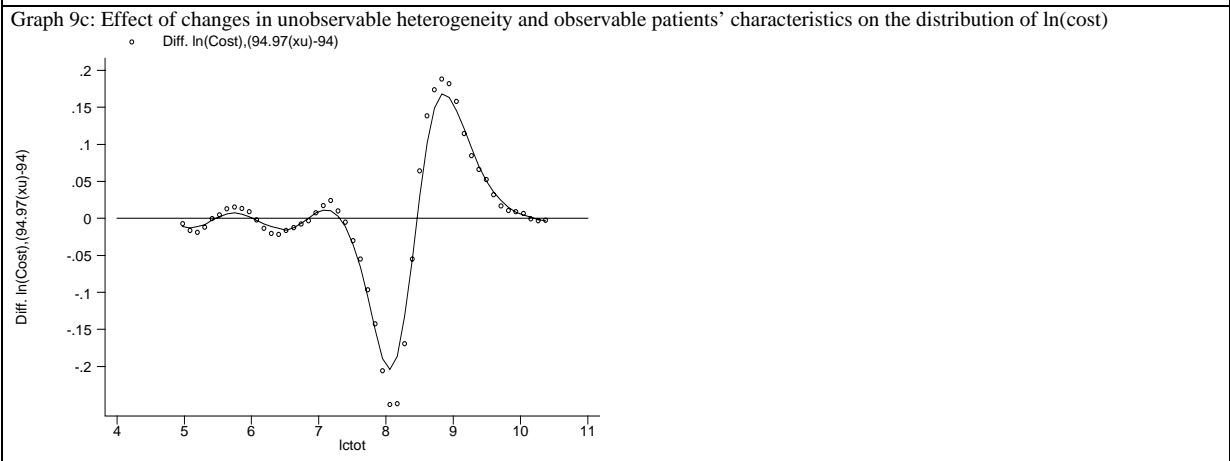
Graph 10: LOS distribution : comparison of effect of changes in behavior
and effect of changes in patients' characteristics.
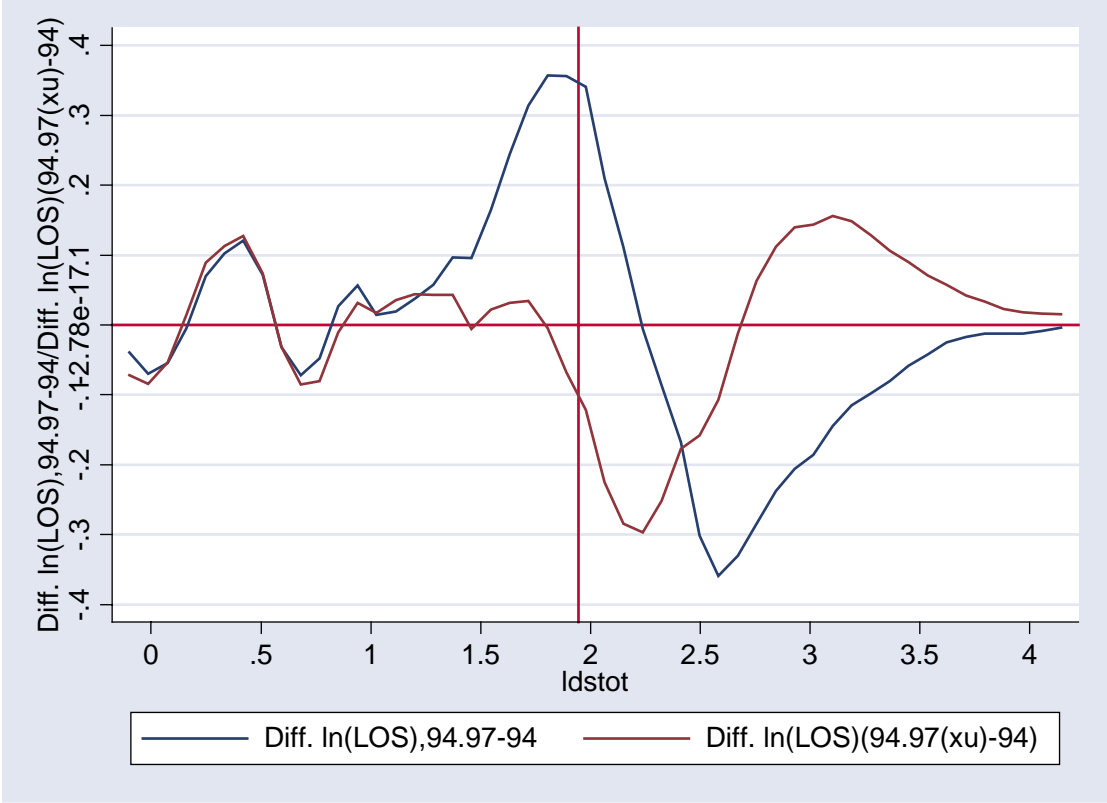
Vertical line : first quartile of ln(LOS), 94.

Annex

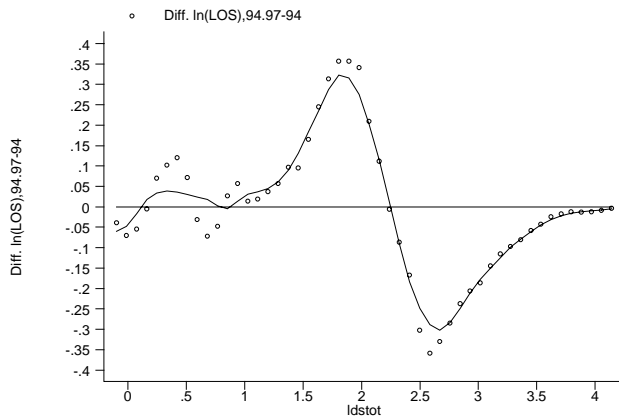Graph 11: Decomposition of change 1994-1997 in the distribution of the logarithm of the
length of stay (called ln(LOS))
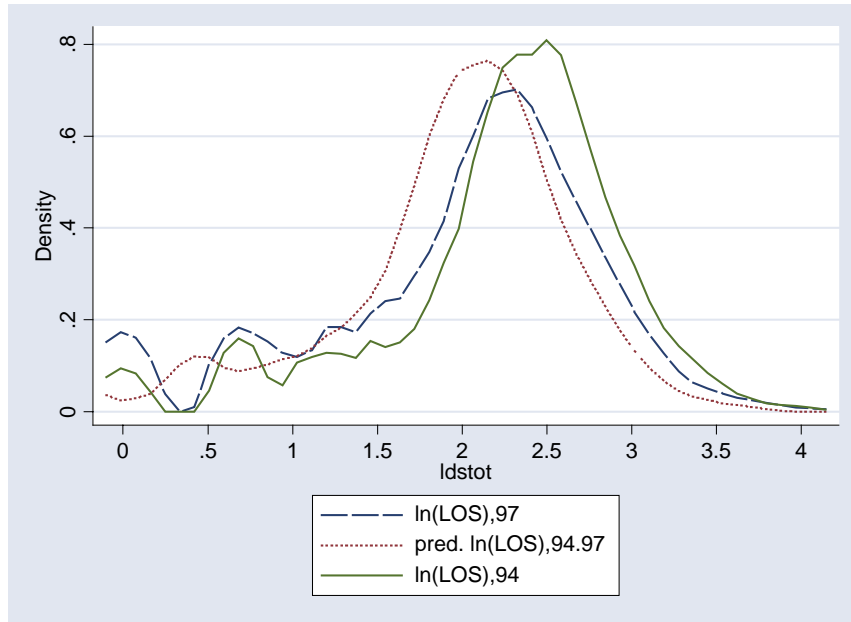
ln(LOS), 94: $d(X_{i0}\beta_0+u_{i0})$, observations 94, coefficients 94
ln(LOS), 94: $d(X_{i0}\beta_1+u_{i0})$, observations 94, coefficients 97
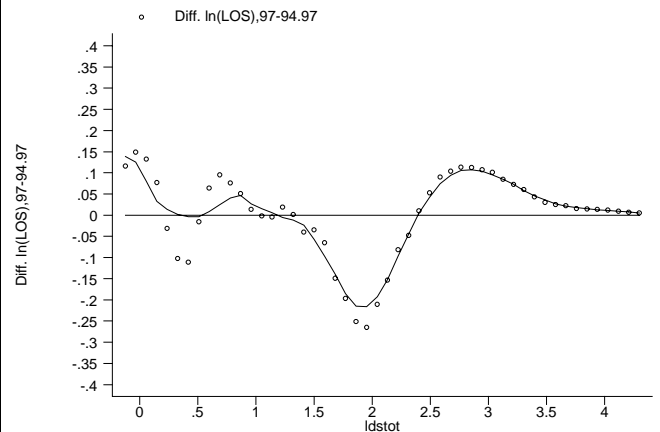ln(LOS), 94: $d(X_{j1}\beta_1+u_{j1})$, observations 97, coefficients 97

Graph 11a: Change in the distribution due to shifts
in the coefficients
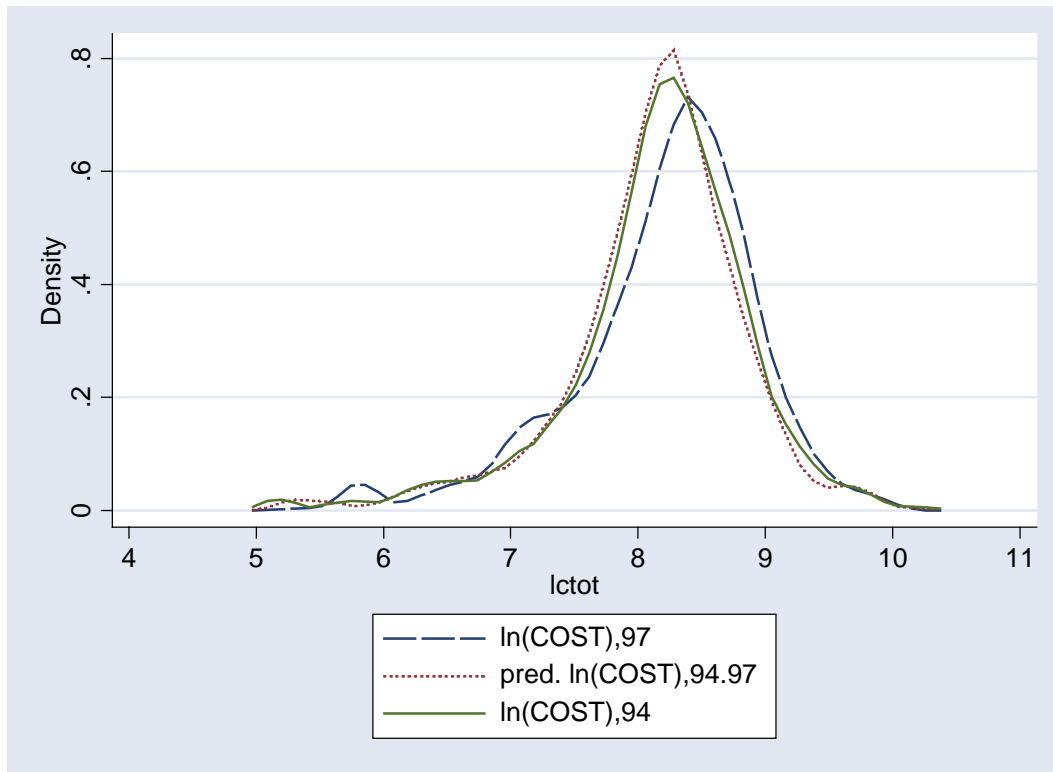$d(X_{i0}\beta_1+u_{i0}) - d(X_{i0}\beta_0+u_{i0})$

Graph 11b: Change in the distribution due to shifts in the
explanatory variables and patients'
unobservable characteristics
$d(X_{j1}\beta_1+u_{j1}) - d(X_{i0}\beta_1+u_{i0})$

Graph 12: Decomposition of change 1994-1997 in the distribution of the logarithm of the cost
of stay (called ln(cost))

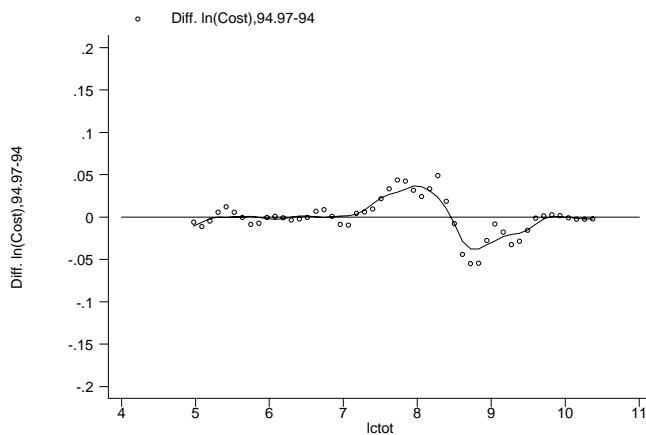*PMSI database: 2,269 and 3,412 AMI stays in 1994 and 1997*

ln(cost), 94: $d(X_{i0}\beta_0+u_{i0})$, observations 94, coefficients 94

ln(cost), 94: $d(X_{i0}\beta_1+u_{i0})$, observations 94, coefficients 97

ln(cost), 94: $d(X_{j1}\beta_1+u_{j1})$, observations 97, coefficients 97

Graph 12a: Change in the distribution due to shifts
in the coefficients
$d(X_{i0}\beta_1+u_{i0}) - d(X_{i0}\beta_0+u_{i0})$

Graph 12b: Change in the distribution due to shifts in
explanatory variables and patients'
unobservable characteristics
$d(X_{j1}\beta_1+u_{j1}) - d(X_{i0}\beta_1+u_{i0})$