Spatial nonprice competition: A network approach

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Abstract

We empirically assess the nature and strength of strategic interactions in industries with spatial nonprice competition. Given that the utilities provided by firms to consumers are unobserved to the researcher, our identification strategy relies on longitudinal data and on the occurrence of firm-level shocks. We use the notion of centrality introduced by network theorists, constructing centrality indicators based on the economy's Leontief matrix. From the evolution of local market shares, we estimate the link between the firms' responses to the shocks and the centrality indicators. The results in our application strongly suggest that the utilities provided by hospitals to patients are strategic complements.

JEL Codes: D4; D85; I1; L1.

Keywords: Strategic interactions; centrality indicators; propagation of shocks; imperfect competition; hospital choice.

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1 Introduction

The purpose of this study is to empirically assess strategic interactions in industries for which spatial differentiation matters and competition cannot be reduced to one observable dimension. To this aim, we adopt a competition-in-utility-space approach that subsumes all the relevant dimensions of competition into an abstract utility index. The utilities offered by firms to consumers are the relevant strategic variables, and our main variables of interest. These utilities, however, are unobserved to the researcher. This is in stark contrast with the case of spatial price competition where the researcher observes the strategic variable and can estimate reaction function slopes based on cross-sectional data, as demonstrated by Pinkse, Slade, and Brett (2002).

In our setting, identification relies on longitudinal data and on the occurrence of firm-level shocks. To identify and estimate the nature and strength of strategic interactions, we take advantage of the fact that firms respond to shocks by adjusting the utilities they provide to consumers. Our methodology exploits the striking differences in the patterns of shock propagation under strategic complementarity and under strategic substitutability. These patterns depend on the properties of the economy's Leontief matrix, as explained by Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015). We use the notion of centrality introduced by network theorists, deriving the expressions of centrality indicators from the Leontief matrix. Next, we incorporate these firm-level centrality indicators as dependent variables into a structural econometric model of shock propagation.

Regarding the available data, we assume that the researcher observes how activity or output at the firm level evolves over time after the industry has been exposed to shocks. Our method applies in configurations where some firms are subject to shocks while some are not.[1] When a firm is subject to a nonzero shock, we call it a $\mathcal{S}$-firm; otherwise we call it a $\mathcal{N}$-firm. Although $\mathcal{N}$-firms have their incentives unchanged, they respond to the shocks on $\mathcal{S}$-firms due to strategic interactions. In equilibrium, the impact of asymmetric shocks can thus be thought of as a two-step process: a transmission stage where the shocks are passed on to the incentives of $\mathcal{S}$-firms; a propagation stage where they spread to the entire industry according to the pattern implied by the Leontief matrix.

To study the propagation of the shocks, we link the firms' responses to their

[1] For instance, financial distress and solvency problems often concern a fraction of all banks; natural disasters and other weather-related events often are region-specific; etc.

position in the industry, more precisely to their position relative to each of the two "subnetworks" $\mathcal{N}$ and $\mathcal{S}$. We describe these positions with indicators that we call $\mathcal{N}$-centrality and $\mathcal{S}$-centrality. The construction of these centrality measures is based on two sets of comparative statics properties that are obtained from the economy's Leontief matrix, by comparing utility changes in response to the shocks at different points of the network.

The first set of comparative statics properties is about the proximity of the subnetworks $\mathcal{N}$ and $\mathcal{S}$. We show that under strategic complementarity the proximity of $\mathcal{S}$-firms (respectively $\mathcal{N}$-firms) magnifies (resp. attenuates) a firm's response to shocks, i.e., is associated with a higher utility change. The result is reversed under strategic substitutability.

Second, firm size or capacity may affect the intensity of strategic interactions, as is the case in a weighted network. We theoretically find that unused capacities are more relevant than total capacities to measure strategic effects. Intuitively, a large but capacity-constrained firm does not exert much of a competitive threat on its neighbors because it cannot steal business from them. Specifically, we find that larger margins of unused capacity are associated with stronger transmission (for $\mathcal{S}$-firms) and lower slopes of reaction functions (for all firms). We are thus able to demonstrate that the margins of unused capacities of competitors play in the same direction as their proximity.

Our empirical methodology applies when the researcher observes a spatial network during a certain period of time after the realization of the shocks. As the primary variable of interest, namely the change in the utility provided by each firm in response to the shocks, is unobserved, it must be inferred from the evolution of network activity, by exploiting both the spatial and time dimensions of the available data. This first step requires estimating the tradeoff between the offered gross utilities and the travel costs incurred by consumers. We are then able to express the magnitude of utility changes in terms of extra travel times that consumers are ready to incur to patronize the concerned firms.

The second step of the method consists in relating utility changes to centrality measures derived from the comparative statics properties presented above. The centrality indicators are defined as increasing functions of the proximity and unused capacities of competitors belonging to each subnetwork. Under strategic complementarity, a higher degree of $\mathcal{S}$-centrality (respectively $\mathcal{N}$-centrality) is associated with a stronger (resp. weaker) response to shocks. The effects are reversed under strategic substitutability, which allows to test whether utilities are strategic complements or strategic substitutes. We assess the strength of strategic interactions by simulating the impact of increases in the centrality indicators on the utility supplied by each firm and hence on the size of its "catchment area".

We illustrate the method with an application to the hospital industry in France, where competition operates only marginally in the price dimension. The industry faced a series of asymmetric shocks when the reimbursement rule for nonprofit hospitals –the "$\mathcal{S}$-firms" in this example– moved from global budgeting to prospective payment. The reimbursement reform, which was implemented gradually over the years 2005 to 2008, caused a series of shocks that dramatically altered the financial incentives faced by $\mathcal{S}$-hospitals. The implied changes in their objective function made them more aggressive in the same way as increased cost efficiencies would have done.

The nature of strategic interactions in this industry is an empirical question. Due to the variety of economic forces at work, the utilities supplied by hospitals to patients may be either strategic complements or strategic substitutes: the costliness of utility pushes towards complementarity while cost-containment efforts and non-financial motives (intrinsic motivation, altruism) push towards substitutability. We use the methodology exposed above to find out which effect dominates.

Panel data covering the four-year phase-in period of the reform make it possible to track hospital activity and patient flows at a detailed geographic level. To infer the utility changes from the evolution of patient flows, we rely on a structural model of hospital choice that places the emphasis on spatial competition, taking advantage of the richness of the data in this dimension.[2] The model follows a discrete choice approach à la Berry (1994) and makes no a priori assumption on the boundaries of market areas. To estimate the travel costs incurred by patients, we develop a novel method that avoids choice set restrictions or normalization assumptions. Our estimation strategy relies on a "triangulation" principle, exploiting the variations of differences in hospital market shares across patient locations. Finally, we place structure on the variations over time of the utilities supplied by the hospitals by introducing indicators for $\mathcal{N}$-centrality and $\mathcal{S}$-centrality. The centrality indicators are computed before the start of the period of interest to avoid endogeneity problems.

After full implementation of the reform, we find that patients are ready to

[2]The database contains about 37,000 distinct patient locations.

travel on average two minutes longer to seek treatment from a $\mathcal{S}$-hospital, relative to a $\mathcal{N}$-hospital. In other words, the hospitals subject to the regulatory shocks have expanded their catchment areas on average by 2 minutes, relative to the other hospitals. This "average relative effect" represents approximately 9% of the median travel time (22 minutes).

Our main findings concern the effect of the hospitals' competitive environments on their response to the shocks. A one-standard-deviation increase in $\mathcal{S}$-centrality *raises* hospital responses by about 2 minutes, an order of magnitude similar to that of the average relative effect. Similarly, a one-standard-deviation increase in $\mathcal{N}$-centrality *lowers* responses by about 2 minutes. These effects are one and a half times stronger when the concerned hospital is itself subject to the reform. In the light of the theoretical analysis, these findings strongly suggest that the utilities supplied to patients are strategic complements.

A final prediction from theory is that a higher marginal utility of revenue is associated with a stronger transmission of the regulatory shock for $\mathcal{S}$-firms. We use the hospitals' debt ratios at the start of the reform as proxies for their marginal utility of revenue. Indeed, more indebted hospitals presumably are in greater need of extra revenues. We find that a one-standard-deviation increase in debt ratio raises hospital responses by about .4 minute. Taken together, the econometric results provide evidence that nonprice competition has been at work as reimbursement incentives were being strengthened for nonprofit hospitals.

The paper is organized as follows. Section 2 briefly connects our work to the network literature. In Section 3, we derive new comparative statics results for the transmission and propagation of asymmetric firm-level shocks to the economy. We also describe our empirical methodology, in particular the construction of centrality indicators. In Section 4, we present our application to the hospital industry, explaining how regulatory shocks have altered the firms' incentives over time. Also, we highlight the richness of the data set in the geographic dimension and discuss the relevant aggregation level. In Section 5, we explain our identification strategy and estimation approach for travel costs and utility changes. In Section 6, we present the estimation results and relate them with theory. Section 7 concludes.

2 Related literature

In a seminal contribution to the network literature, Bonacich (1987) introduces an eponymous measure of centrality based on the number of paths connecting each node to the network, each path being weighted inversely to its length. The notion of centrality has later been linked to non-cooperative game theory. Assuming linear-quadratic payoffs, hence linear reaction functions, Ballester, Calvó-Armengol, and Zenou (2006) prove that equilibrium actions coincide with Bonacich centrality. Two recent studies, Belhaj, Bramoullé, and Deroïan (2014) and Bramoullé, Kranton, and D'Amours (2014), relax the linearity assumption, addressing separately the cases of strategic complementarity and strategic substitutability. Finally, Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) highlight the importance of the Leontief matrix to describe the shifts in equilibria that result from firm-specific shocks.[3] In this article, we examine Leontief matrices in various configurations to determine how agents' responses to shocks depend on their position in the network. We are thus able to construct centrality measures that reflect the spatial distribution of agents as well as their respective weight in the network.

The empirical identification of network interactions is an active area of research. Most existing studies use cross-sectional data and exploit properties of static Nash equilibria to derive instrumental variables for peer effects. Methodological contributions include Manski (1993), Lee (2007) and Bramoullé, Djebbari, and Fortin (2009). The latter exhibit sufficient conditions for identification, using neighbors of neighbors' covariates as valid instruments. In a recent application, Acemoglu, Garcia-Jimeno, and Robinson (2015) estimate a model of state capacity investment, infer the shape of reaction functions from cross-sectional data, and find strategic complementarities in the network of Colombian municipalities.

We depart from the static literature by examining patterns of shock propagation over time. We exploit the longitudinal dimension of panel data after a shock has been transmitted to assess the nature and strength of network interactions. The propagation of shocks provides us with the exogenous source of variation required for the identification of network interactions. The diffusion of shocks over time and space enables us to recover the magnitudes of agents' responses. Moreover, by estimating the effect of the centrality indicators, we can determine whether actions are strategic complements or strategic substitutes.

[3] The Leontief matrix accounts for the reaction of immediate neighbors (direct effect) but also for the whole set of network interactions (indirect effects).

It is worthwhile contrasting our ex post perspective to ex ante approaches where the expected effect of small shocks (before they realize) is null at the equilibrium. The latter property is called "certainty equivalence" by Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015). In our framework, the consequences of actual shock realizations are tracked down, and therefore certainty equivalence does not apply: comparative statics may be derived thanks to first-order linearization around the equilibrium state.

Finally, compared to the studies cited above, one distinguishing feature of our methodology is that we do not observe the strategic variable of interest, namely the utility supplied by firms. We circumvent this difficulty by estimating a structural model of consumer behavior and inferring utility variations over time from the evolution of local market shares. Then, we relate those utility variations to centrality indicators and characterize strategic interactions. Furthermore, firm-level shocks in our setting do not directly affect the utilities supplied by firms, but instead alter underlying parameters that change their incentives. Accordingly, when deriving comparative statics properties and constructing centrality indicators, we model both the transmission and propagation stages, taking into account the changes in individual incentives caused by exogenous shocks as well as the equilibrium effects due to network interactions.

3 Analytical framework

In this section, we set up a general oligopoly model where firms compete in utility to attract consumers. We study how shocks on the firms' incentives propagate to the market at the oligopolistic equilibrium. Specifically, we relate the changes in the utilities supplied by firms to their local market environment. The comparative statics predictions differ according to the nature of strategic interactions, providing a way to test whether utilities are strategic complements or strategic substitutes. Finally, we present an empirical test methodology when the researcher observes the evolution of network activity following the shocks. We describe the position of each firm in the network with centrality indicators, and infer the utility changes from a structural model of consumer behavior.

3.1 Transmission and propagation of shocks

Throughout the article, we adopt a discrete-choice framework where a consumer's net utility is the sum of a firm specific term and an idiosyncratic consumer-level shock:

$$U_{ij} = u_j + \zeta_{ij}. \tag{1}$$

As put by Armstrong and Vickers (2001) when presenting the competition-in-utility-space approach, we can think of u_j as the "average" utility offered by firm j to the population of consumers. Consumers (indexed by i) may be heterogeneous in various dimensions, with the corresponding heterogeneity ζ_{ij} entering utility in an additive manner. We hereafter place the emphasis on one particular dimension of heterogeneity, namely consumer location, and on the resulting implications for spatial competition. We assume that firms do not discriminate across consumers according to location; more generally, we assume away any discrimination based on consumer characteristics.

Individual demand at the consumer level is obtained by choosing the firm that yields the highest value of U_{ij} in (1). In general, consumers may also consider the option of not purchasing the good, in which case the model should account for the corresponding utility $U_{i0} = \zeta_{i0}$. Integrating over the disturbances ζ_{ij}, we obtain the aggregate demand addressed to firm j, $s^j(u_j, u_{-j})$, which depends positively on the utility supplied by that firm, and negatively on the set of utilities supplied by its competitors. Normalizing the total number of consumers to one, the demand function can be interpreted in terms of either market shares or number of served consumers.

Firms set the utility supplied to consumers to maximize their objective function V^j. The marginal incentive of firm j to increase utility, $\mu^j = \partial V^j / \partial u_j$, is assumed to depend on a firm-level parameter r_j that may for instance represent a factor affecting costs or revenues (input price, interest rate, etc.). The first-order conditions of the firms' maximization problem are obtained by setting those incentives equal to zero:

$$\mu^j(u_j, u_{-j}; r_j) = 0. \tag{2}$$

The above condition implicitly defines firm h's reaction function, which we denote by $u_j = \rho^j(u_{-j}; r_j)$. When these functions are increasing in u_{-j}, the utilities supplied by firms are strategic complements. When they are decreasing, utilities are strategic substitutes. An oligopolistic equilibrium is characterized by the solution to the system (2) together with the second-order conditions $\partial\mu^j/\partial u_j < 0$.[4]

We want to understand how the equilibrium is shifted after the firm-level parameters r_j are hit by small shocks $\mathrm{d}r_j$, e.g., rises in input prices or interest rates. Differentiating each of the first-order condition $\mu^j = 0$ with respect to r_j yields

$$\frac{\partial\mu^j}{\partial u_j}\mathrm{d}u_j + \frac{\partial\mu^j}{\partial u_{-j}}\mathrm{d}u_{-j} + \frac{\partial\mu^j}{\partial r_j}\mathrm{d}r_j = 0. \tag{3}$$

The shift in equilibrium caused by the shocks results from both firm-level mechanical transmission and propagation through strategic interactions. Mechanical transmission refers to the effect that would prevail in the absence of strategic interaction, i.e., if the utilities supplied by the competitors, u_{-j}, were fixed. We write the transmission effect as $\Delta_j\mathrm{d}r_j$ where the *transmission rate* Δ_j is given by

$$\Delta_j = \left.\frac{\partial u_j}{\partial r_j}\right|_{u_{-j}} = -\frac{\partial\mu^j/\partial r_j}{\partial\mu^j/\partial u_j}. \tag{4}$$

We denote by Δ the diagonal matrix with Δ_j on its diagonal. The vector $\Delta\mathrm{d}r$ measures the effect of the shock on firm utilities if strategic interactions were neutralized. From the second-order condition, the sign of Δ_j is the same as that of $\partial\mu^j/\partial r_j$, which in many practical cases is derived from economic intuition. For instance, shocks that raise marginal costs should generally depress the incentives to attract consumers.[5] Hereafter, we normalize r_j so that Δ_j is positive, and hence $\mathrm{d}r_j > 0$ represents a positive shock on incentives.

To account for equilibrium propagation, the mechanical transmission effects need to be "expanded" as follows. For $j \neq k$, we denote by g_{jk} the slope of the reaction function ρ^j in the direction k, i.e.

$$g_{jk} = \left.\frac{\partial\rho^j}{\partial u_k}\right|_r = -\frac{\partial\mu^j/\partial u_k}{\partial\mu^j/\partial u_j}. \tag{5}$$

Setting $g_{jj} = 0$, we introduce the matrix G with generic entry g_{jk},[6] as well as its inverse $L = (I - G)^{-1}$. Rearranging (3) yields

$$\mathrm{d}u = L\Delta\,\mathrm{d}r. \tag{6}$$

[4] Dixit (1986) provides sufficient conditions for equilibrium stability. The simplest set of sufficient conditions is obtained by requiring strict diagonal dominance for the Jacobian matrix $\mathrm{D}_u\mu$ with generic entry $\partial\mu^j/\partial u_k$.

[5] In some cases, the presence of revenue effects might blur the analysis, see Appendix C.

[6] In a simple example with four firms, the matrix G is given by (A.1) in Appendix A.

The *propagation matrix* L – a Leontief matrix as described in Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) – summarizes how the mechanical effects $\Delta \mathrm{d}r$ propagate through the whole set of strategic interactions to yield equilibrium outcome. The generic element of L, which we denote hereafter by l_{jk}, expresses the extent to which the mechanical effect of the shock on firm j, namely $\Delta_j \mathrm{d}r_j$, affects the utility offered by firm k in equilibrium: $\mathrm{d}u_k = l_{jk}\Delta_j \mathrm{d}r_j$.

Asymmetric shocks Throughout this study, we consider asymmetric situations where the shocks are positive and uniform for a subset of firms that we call $\mathcal{S}$, and are zero in the complementary subset, which we denote by $\mathcal{N}$. Formally: $\mathrm{d}r_j = \mathrm{d}r > 0$ for j in $\mathcal{S}$ and $\mathrm{d}r_j = 0$ for j in $\mathcal{N}$. By construction then, positive transmission exists only for $\mathcal{S}$-firms. We are interested in assessing the extent to which $\mathcal{N}$-firms are affected through the equilibrium effects embodied by the Leontief matrix L. The changes in equilibrium utilities are given by

$$\mathrm{d}u_j = \left(\sum_{k \in \mathcal{S}} l_{jk}\, \Delta_k \right) \mathrm{d}r. \tag{7}$$

The summation term at the right-hand side of the fundamental formula (7) depends on fine details about firm characteristics and market geography. A fully general analysis of the economic forces that determine both the mechanical transmission rates Δ_k and the Leontief coefficients l_{jk} seems out of reach. To derive comparative statics properties about the utility changes $\mathrm{d}u_j$, we consider hereafter a spatial competition model with a single dimension of consumer heterogeneity, namely geographic location.

3.2 Market geography

We now investigate how the geographic position of the firms within the network affects their responses to shocks. In the remainder of this section, we assume that consumer net utility when patronizing firm j is the gross utility offered by that firm net of linear transportation costs

$$U_{ij} = u_j - \alpha d_{ij},$$

where the parameter α reflects the tradeoff between the average gross utility offered by a firm and the distance between that firm and the consumer home.[7] This is the special case of the additive model (1) where $\zeta_{ij} = -\alpha d_{ij}$. Specifically, we use Salop (1979)'s circular city model of spatial differentiation to model consumer demand. To avoid uninteresting complications, we concentrate on market configurations with four active firms and full market coverage. In some of the examples below, it is important that the firms are not located in an equidistant manner along the circle. We also assume the utility supplied by competitors enters a firm's objective function only through the demand s^j. It follows that the reaction function ρ^j depends only on the utilities supplied by the two immediate neighbors. We denote by ρ_j the slope of the reaction function, $\rho_j = \partial\rho^j/\partial u_{-j}$.

We first investigate how the proximity of $\mathcal{S}$-firms and $\mathcal{N}$-firms affects a firm's response to the shock. For this purpose, we assume that ρ_j and Δ_j are constant across firms. As $\Delta_j = \Delta > 0$, we know from the fundamental equation (7) that $\mathrm{d}u_j$ is proportional to the sum of the Leontief coefficients, $\sum_{k\in\mathcal{S}} l_{jk}$. We must therefore understand how this sum depends on the market configuration. In Appendix A, we check that l_{jk} can be written $l(0)$ if $j = k$, $l(1)$ if j and k are adjacent firms, and $l(2)$ if a third firm is interposed between j and k.

Average relative effect We now establish that $\mathcal{S}$-firms on average increase the utility supplied to consumers relative to $\mathcal{N}$-firms. This property holds irrespective of whether utilities are strategic complements or strategic substitutes:

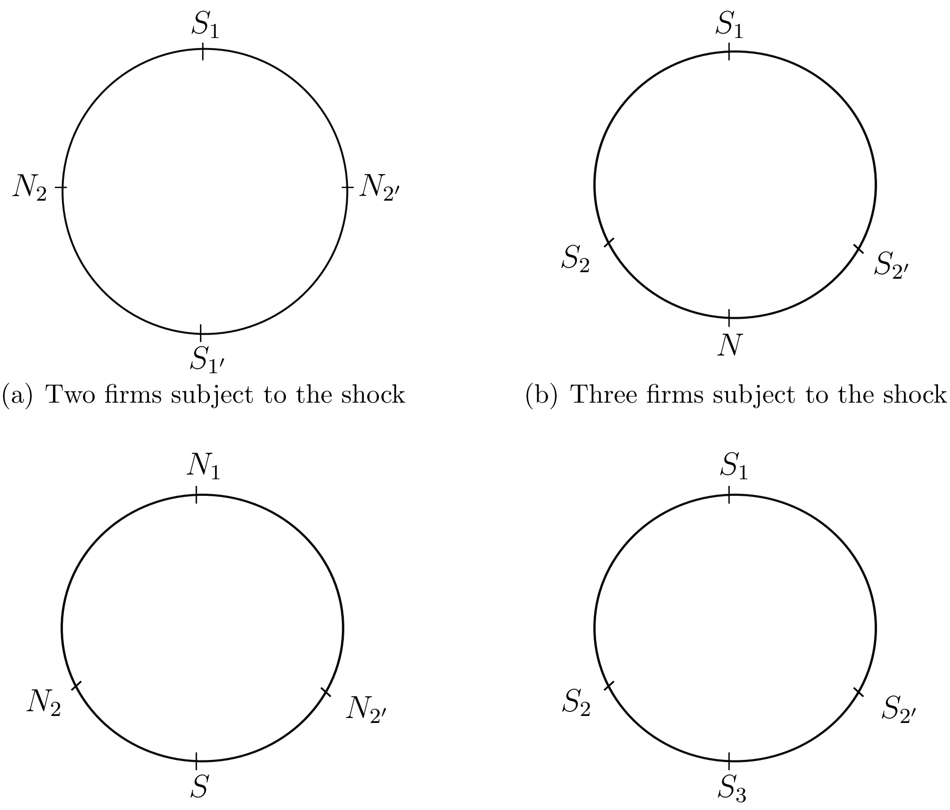
$$\frac{1}{|\mathcal{S}|}\sum_{j\in\mathcal{S}} \mathrm{d}u_j - \frac{1}{|\mathcal{N}|}\sum_{k\in\mathcal{N}} \mathrm{d}u_k > 0, \tag{8}$$

where $|\mathcal{S}|$ and $|\mathcal{N}|$ denote the number of firms in $\mathcal{S}$ and $\mathcal{N}$. In the situation represented on Figure 1(a), we have $\mathrm{d}u_{S_1} = \mathrm{d}u_{S_{1'}} = l(0) + l(2)$ and $\mathrm{d}u_{N_2} = \mathrm{d}u_{N_{2'}} = 2l(1)$, so inequality (8) is equivalent to

$$\mathrm{d}u_{S_1} - \mathrm{d}u_{N_1} = [l(0) + l(2) - 2l(1)]\,\Delta\mathrm{d}r > 0. \tag{9}$$

When the utilities supplied by the firms are strategic complements, all three transition coefficients $l(0)$, $l(1)$, and $l(2)$ are positive, and all firms supply a higher

[7] Multiplying all utilities u_j as well as the parameter α by the same positive factor does not change the consumer problem; in this simplified setting, these parameters are only identified up to a scale factor.



(a) Two firms subject to the shock
(b) Three firms subject to the shock
(c) One firm subject the shock
(d) Four firms subject the shock

Figure 1: Market configurations with four firms

utility following the shock. In Appendix A, we check that the function $l(.)$ is convex, which yields (9). On the other hand, when the utilities are strategic substitutes, N_2 and $N_{2'}$ respond to utility rises at firms S_1 and $S_{1'}$ by *decreasing* the utility they provide to consumers; $l(0)$ and $l(2)$ are positive, while $l(1)$ is negative, making inequality (9) obvious. Inequality (8) is easy to check in the other configurations shown on Figure 1.

Proximity of firms not subject to the shock Going beyond *average* relative effects, we now want to compare the relative effect of the shock *within* each of the two groups $\mathcal{S}$ and $\mathcal{N}$. We first investigate how the proximity of $\mathcal{N}$-firms affects the response of $\mathcal{S}$-firms. To this aim, we consider the market configuration depicted on Figure 1(b), with three $\mathcal{S}$-firms, S_1, S_2 and $S_{2'}$, symmetrically located on the circle, and one $\mathcal{N}$-firm, N, interposed between S_2 and $S_{2'}$. The three firms subject to the shock are symmetric in any dimension but the proximity of a firm not subject to the shock. The changes in gross utility by these three firms are $\mathrm{d}u_{S_1} = [l(0) + 2l(1)]\,\Delta\mathrm{d}r$ and $\mathrm{d}u_{S_2} = \mathrm{d}u_{S_{2'}} = [l(0) + l(1) + l(2)]\,\Delta\mathrm{d}r$, which yields the following difference in utility changes between the firms:

$$\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2} = \mathrm{d}u_{S_1} - \mathrm{d}u_{S_{2'}} = [l(1) - l(2)]\,\Delta\mathrm{d}r. \tag{10}$$

When the utilities supplied by the firms are strategic complements, we check in Appendix A that $l(1) > l(2) > 0$, implying then that the double difference $\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2}$ is positive: the proximity of the $\mathcal{N}$-firm attenuates the effect of the shock. On the contrary, when the utilities are strategic substitutes, $l(1)$ is negative while $l(2)$ is positive, implying that the double difference is negative: being close to a $\mathcal{N}$-firm magnifies the response of $\mathcal{S}$-firms. These comparative statics properties are reported in cells B1 and B3 of Table 1.

Table 1: Comparative statics properties for utility changes $\mathrm{d}u_j$

	Under strategic complementarity		Under strategic substitutability	
	$j \in \mathcal{S}$ (1)	$j \in \mathcal{N}$ (2)	$j \in \mathcal{S}$ (3)	$j \in \mathcal{N}$ (4)
A. Own unused capacity	$+^{(*)}$	-	$+^{(*)}$	-
B. Proximity and unused capacity of competitors $k \in \mathcal{N}$	-	-	+	+
C. Proximity and unused capacity of competitors $k \in \mathcal{S}$	$+^{(*)}$	$+^{(*)}$	$-^{(*)}$	-

Notes: The negative sign in cell B1 means that under strategic complementarity, the response of $\mathcal{S}$-firm j (relative to that of other $\mathcal{S}$-firm) is lower when j is closer to $\mathcal{N}$-firms k with larger unused capacities.
Cells B1 and B3 are based on the configuration of Figure 1(b). Cells C2 and C4 are based on that of Figure 1(c). Cells A1, C1, A3, and C3 are based on Figure 1(d). Cells A2, B2, A4, and B4 are based on Figure 3.
The results marked with (*) assume that the comparative statics regarding unused capacities is governed by their effect on mechanical transmission rates.

Proximity of firms subject to the shock The proximity of $\mathcal{S}$-firms plays in the opposite direction. Consider the configuration shown on Figure 1(c), namely three $\mathcal{N}$-firms, N_1, N_2 and $N_{2'}$, that are symmetrically located on the circle, and one $\mathcal{S}$-firm, S, located between N_2 and $N_{2'}$. The three firms not subject to the shock are symmetric in any dimension but the proximity of a firm subject to the shock. The changes in gross utility by these three firms are $\mathrm{d}u_{N_2} = \mathrm{d}u_{N_{2'}} = l(1)\Delta\mathrm{d}r$ and $\mathrm{d}u_{N_1} = l(2)\Delta\mathrm{d}r$, which yields the double difference $\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1} = \mathrm{d}u_{N_{2'}} - \mathrm{d}u_{N_1} = [l(1) - l(2)]\,\Delta\mathrm{d}r$. Utility changes are, again, ordered in the same way as $l(1)$ and $l(2)$. Under strategic complementarity, the proximity of a $\mathcal{S}$-firm is associated with a stronger rise in consumer gross utility. The result is reversed under strategic substitutability. These comparative statics properties are reported in cells C2 and C4 of Table 1.

3.3 The role of unused capacities

In this section, we argue that the magnitude of a firm' response is not only affected by the network geography but also by the relative "weights" of all firms. We suggest that the weights are best approximated by unused capacities. Under natural assumptions regarding firms' costs, we show that unused capacities of neighboring $\mathcal{N}$-firms and $\mathcal{S}$-firms affect a firm's response to shocks in the same way as the proximity of those firms. The comparative statics results are reported in Table 1. The reader who is primarily interested in the empirical methodology should proceed directly to Section 3.4.

Specifically, we assume that marginal costs increase with the utility supplied to consumers and can be reduced by exerting cost-containment managerial effort. Furthermore, we assume that a firm finds it more costly to increase the utility it supplies to each consumer and more difficult to reduce its marginal cost when it operates at, or close to, full capacity. The underlying logic is that when a firm operates close to full capacity the staff is busy with everyday tasks, and therefore raising consumer utility requires hiring new staff, or having the existing staff work longer hours, or changing organizational processes. The former two actions imply additional personnel expenses, while the latter two imply extra managerial efforts.[8] We find that under these circumstances larger margins of unused capacities are associated with stronger transmission rates Δ_j (for $\mathcal{S}$-firms) and lower slopes of the reaction functions ρ_j (for all firms).

The result regarding transmission is intuitive: a $\mathcal{S}$-firm that is already operating at full capacity has little incentive or ability to attract extra consumers. Regarding reaction functions, the intuition is as follows. When a competitor increases u_{-j}, firm j faces a reduction in demand which has two consequences. First, increasing individual consumer utility is less costly (because the firm now has less consumers), hence an incentive to *rise* u_j; this effect is *stronger* when the firm operates at or close to full capacity because utility is particularly costly in this

[8]When the managerial team has little time for thinking about innovations, efforts to improve consumer experience or reduce marginal costs imply high non-pecuniary costs.

region. Second, reducing marginal costs is less profitable (because, again, the firm serves less consumers), hence a lower cost-containment effort, a higher marginal cost, and an incentive to *lower* u_j; this effect, however, is *weaker* when the firm operates at or close to full capacity because then the cost-containment effort is already weak due to high managerial costs and hence it cannot be much reduced. A formal treatment of these two channels is provided in Appendix B, see Lemma B.1.

Equipped with the above comparative statics results about transmission rates and reaction functions, we are now able to describe how the utility changes $\mathrm{d}u_j$ depend on the unused capacity of the concerned firms and of those of neighboring $\mathcal{N}$-firms and $\mathcal{S}$-firms.

Unused capacities of $\mathcal{N}$-firms We start by studying the role of unused capacities of firms that are not subject to the shock. These capacities operate through one single channel, namely the reaction function of the concerned firms.

To understand the impact of the unused capacity of a $\mathcal{N}$-firm on the response of neighboring firms in $\mathcal{S}$, we revisit the case of Figure 1(b) with three $\mathcal{S}$-firms, S_1, S_2 and $S_{2'}$, and one $\mathcal{N}$-firm, N. Assuming that the four firms have the same transmission rate and reaction function, we have seen above that the double difference $\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2}$ given by (10) is positive under strategic complementarity. We now allow firm N's unused capacity to take any value, maintaining the symmetry assumption for the three $\mathcal{S}$-firms. If the common reaction function of the $\mathcal{S}$-firms is upward-sloping, we check in Appendix A that the magnitude of the positive double difference $\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2}$ increases with N's unused capacity. In other words, the relative effect of the proximity of a $\mathcal{N}$-firm is amplified by its amount of unused capacity. The result is reversed under strategic substitutability. These properties are reported in cells B1 and B3 of Table 1.

To understand the impact of the unused capacity of a $\mathcal{N}$-firm on its own response or on that of neighboring $\mathcal{N}$-firms, we consider the configuration with five firms shown on Figure 3 in Appendix A. (We use this more complicated configuration because we need at least one $\mathcal{S}$-firm for a shock to exist in the economy.) The results reported in cells A2 and A4 of Table 1 show that own unused capacities are associated with a weaker firm response. The results in cells B2 and B4 express that large unused capacities at neighboring firm play in the same direction as the proximity of these firms (see Appendix A for details).

Unused capacities of $\mathcal{S}$-firms We now turn to the role of unused capacities of neighboring firms subject to the shock. The analysis is a bit more involved because the capacities of $\mathcal{S}$-firms operate through two channels, namely mechanical transmission and propagation through reaction functions.

To understand the impact of the unused capacity of a $\mathcal{S}$-firm on the response of neighboring $\mathcal{N}$-firms, we consider the configuration shown on Figure 1(c), with three $\mathcal{N}$-firms, N_1, N_2 and $N_{2'}$, and one $\mathcal{S}$-firm, S. The larger the unused capacity of firm S, the stronger its transmission rate Δ and the lower the slope of its reaction function, ρ_S. We find in Appendix A that under strategic substitutability the double difference $\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1}$ is negative and unambiguously decreases with S's unused capacity. Under strategic complementarity, the double difference is positive; it increases with S's unused capacity if we assume that the comparative statics is driven by the differences in transmission rates caused by unused capacity. These results are reported in cells C2 and C4 of Table 1.

Finally, to understand the impact of the unused capacity of a $\mathcal{S}$-firm on its own response or on that of neighboring $\mathcal{S}$-firms, we consider the configuration shown on Figure 1(d), with four $\mathcal{S}$-firms. We check in Appendix A that the double differences $\mathrm{d}u_{S_2} - \mathrm{d}u_{S_1}$, $\mathrm{d}u_{S_3} - \mathrm{d}u_{S_2}$ and $\mathrm{d}u_{S_3} - \mathrm{d}u_{S_1}$ increase with the magnitude of the transmission rate of S_3. This channel tends to make these differences increase in the unused capacity of that firm. These results are reported in cells A1, C1, A3 and C3 of Table 1.

3.4 Empirical strategy

Our empirical methodology applies when the researcher can observe the economy during a certain period of time after the realization of the shocks. It assumes that the firms' managers do not anticipate the shocks, have a short time horizon (e.g., due to high job mobility), and therefore set at each period the utility offered to consumers that maximizes their static objective function. In contrast with most of the network literature, we face the additional difficulty that the strategic variables, namely the utilities supplied to consumers, are not observable. To overcome this difficulty, we propose to infer the changes in the utilities supplied by firms from the evolution of network activity. Then we relate these changes to measures of centrality derived from the comparative statics properties reported in Table 1.

The first step of the method requires a structural econometric model whose specification should be adapted to each particular situation. At this point, we sketch a general discrete-choice framework with consumer utility

$$U_{ijt} = u_{jt} - \alpha d_{ij} + \xi_{jt} + \varepsilon_{ijt},$$

where u_{jt} is the "average" gross utility offered by firm j at date t, d_{ij} is the distance between consumer i and firm locations, ξ_{jt} a firm-level, time-varying disturbance, and ε_{ijt} a consumer-level idiosyncratic shock.[9] The above functional form, which assumes that travel disutility costs increase linearly with distance, has the advantage of providing a simple conversion rate between utility and travel time. Consumers are ready to incur higher travel costs to patronize firms that increase gross utility over time. The conversion rate offers a convenient way to express utility changes in terms of changes in the firms' catchment areas.

The empirical counterparts of the theoretical utility changes $\mathrm{d}u_j$ are the time differences $\delta u_{jt} = u_{jt} - u_{j,t-1}$. We place structure on these differences by introducing centrality indicators that quantify the exposure to competition from $\mathcal{N}$-firms and $\mathcal{S}$-firms. The comparative statics properties established in the above sections show that proximity and unused capacity play in the same direction.[10] Accordingly, we define centrality indicators as increasing functions of proximity and unused capacities (UC in short) of competitors:

$$\text{Central}_j^S = \sum_{k \neq j, k \in \mathcal{S}} \Phi\left(d_{jk}, \text{UC}_{k,t_0}\right), \quad \text{Central}_j^N = \sum_{k \neq j, k \in \mathcal{N}} \Phi\left(d_{jk}, \text{UC}_{k,t_0}\right), \qquad (11)$$

where the function Φ is decreasing in its first argument and increasing in its second one. We compute the indicators before the realization of the shock to avoid endogeneity biases (the shocks occur after t_0 in the above equation).

We let the utility changes depend on the two centrality indicators interacted with dummy variables for whether the concerned firm belongs to $\mathcal{N}$ or $\mathcal{S}$. We also let utility changes depend on the firms' unused capacity. We are thus able to test all the predictions of Table 1, and therefore to determine whether utilities are strategic complements or strategic substitutes.

Using the utility changes $\delta \hat{u}_{jt}$ estimated from the model, we can quantify the extent to which the catchment areas of $\mathcal{S}$-firms change relative to those of $\mathcal{N}$-

[9] We postpone the discussion of identification and estimation issues to Section 5.

[10] The analysis of Section 3.3 explains why unused capacities are more relevant than total capacities to reflect the competitive pressure exerted by neighboring firms.

firms following the realization of the shocks, i.e., to estimate the magnitude of the "average relative effects" given by the left-hand side of (8). Also, and importantly, we are able to assess the strength of strategic interactions by simulating the effect of an increase in each of the two centrality indicators on the utility supplied by firms –and hence on the size of their catchment area.

4 An application to the hospital industry

The asymmetric shock considered in the remainder of the article results from a reimbursement reform that applied to about half of all French hospitals over the years 2005 to 2008. After describing the payment shock, we explain how the regulatory shock altered the hospitals' financial incentives. Finally we provide details on the industry and present our data set.

4.1 The payment reform

We consider the introduction in France of an activity-based, fixed-price, prospective payment system. Although a similar reimbursement rule has been introduced by the U.S. federal government for the Medicare program in 1983, there exists a notable difference between the American and French reforms, namely their starting point: a cost-based reimbursement system in the U.S. versus global budgeting in France.

More precisely, the policy reform considered in this article applied to the set of all nonprofit hospitals, either government-owned or private. To stick with theory, this set is denoted by $\mathcal{S}$. Before March 2004, nonprofit hospitals were funded through an annual lump-sum transfer from the government (*"global dotation"*) which varied very little with the nature or evolution of their activity. The payment rule has gradually been moved to an activity-based payment, where activity is measured by using (successive versions of) a diagnosis-related group (DRG) classification as is standard in most developed countries. For the concerned hospitals, activity-based revenues accounted for 10% of the resources in 2004, the remaining part being funded by a residual dotation. The share of the budget funded by activity-based revenues increased to 25% in 2005, 35% in 2006, 50% in 2007 and finally to 100% in 2008. The residual dotation has then been totally suppressed in 2008.[11]

We now describe the rules in force for the set $\mathcal{N}$ of all private, for-profit clinics. (The sets $\mathcal{N}$ and $\mathcal{S}$ are therefore complementary in the universe of all hospitals.) Before 2005, for-profit clinics were indeed already submitted to a prospective payment based on DRG prices. The reimbursement rates, however, included a *per diem* fee: as a result, they depended on the length of stay. Moreover, these rates were negotiated annually and bilaterally between the local regulator and each clinic, and were consequently history- and geography-dependent. Starting 2005, all for-profit clinics are reimbursed the same rate for a given DRG and those rates no longer depend on length of stay.[12]

In sum, between 2005 and 2008, the payment rule applying to private, for-profit clinics has been constant, while nonprofit hospitals have been submitted to increasingly strong reimbursement incentives. Although these clinics have not been subject by the reform, they may have been affected indirectly through strategic market interactions.

4.2 Regulatory shock and hospital incentives

To place the problem into the framework of Section 3, we model the payment reform as a change in the parameters of a two-part reimbursement rule: hospital h receives a lump-sum transfer $\bar{R}_h$ plus a payment per discharge $r_h \geq 0$. For-profit clinics –the $\mathcal{N}$-hospitals– experience no policy change: $\delta r_h = 0$. Nonprofit hospitals –the $\mathcal{S}$-hospitals– experience during four successive years policy variations $\delta r > 0$ and $\delta \bar{R}_h < 0$. As a result of the changes $\delta r > 0$, an extra admission brings more revenue to $\mathcal{S}$-hospitals, implying that, all else equal, their incentives to attract patients are stronger. Intuitively, these changes have the same effect as reductions in marginal costs.

To formalize this intuition and discuss the role of lump-sum transfers, we set up in Appendix B a standard nonprice competition model where, as in Section 3.3, marginal costs increase with the utility supplied to patients and can be reduced by cost-containment effort. The nature of strategic interactions is ambiguous in

[11] A series of lump-sum transfers have subsisted, some of which are linked to particular activities such as research, teaching or emergency services, while others have more distant connections to specific actions. In 2007, the various transfers accounted for 12.7% of resources.

[12] The DRG-based reimbursement schemes are different in both level and scope for $\mathcal{S}$-hospitals and $\mathcal{N}$-hospitals. In the latter group, DRG rates do not cover physician fees, which are paid for by the health insurance system as in the community market.

this setting. On the one hand, the costliness of quality pushes towards complementarity: when a competitor raises u_{-h}, hospital h loses market shares, hence a lower marginal cost and an extra incentives to raise u_h. On the other hand, cost-containment efforts push towards strategic substitutability. As u_{-h} rises, fewer patients are treated by hospital h, the endogenous cost-containment effort falls because the reduced marginal cost applies to fewer patient admissions, hence a higher marginal cost and an incentive to lower the utility supplied to patients.[13]

The model allows for lots of heterogeneity across hospitals in terms of cost structure and managerial preferences. Due to the quadratic specification of the objective functions, the marginal incentives $\mu^j(u_j, u_{-j}; r_j)$ are linear in all their arguments, so that the first-order approximation used in Section 3 is exact and the comparative statics results derived there are valid for non-marginal shocks.

The role of the change in lump-sum transfers is discussed in Appendix C. When the incentives are linear, there are no revenue effects: the changes in lump-sum transfers $\delta \bar{R}_h < 0$ play no role, the changes in the DRG rates $\delta r_h > 0$ obviously strengthen the hospitals' incentives; in other words, the transmission rates Δ_h are positive for all $\mathcal{S}$-firms. In the case of the French reform studied in this article, the regulator reduced the lump-sum transfers to limit as much as possible the induced variations in hospital revenues. When revenue effects are neutralized, transmission rates are positive: given the behavior of their competitors, the hospitals subject to the reform are encouraged to increase the utility offered to consumers.

4.3 Data and industry background

In France, more than 90% of hospital expenditures are covered by the public and mandatory health insurance scheme. Supplementary insurers (including the state-funded supplementary insurance for the poor) cover much of the remaining part.[14] For instance, supplementary insurers generally cover the fixed daily fee that hospitals charge for accommodation and meals. On the other hand, they may not fully cover some extra services (e.g., individual room with television) that some consumers may want to pay for, or extra-billings that certain prestigious doctors may charge. Although as Ho and Pakes (2014) we do not observe patient individual out-of-pocket expenses in the data, we know from the National Health Accounts that, at the aggregate level, out-of-pocket expenses have remained low

[13] These two effects appear in Brekke, Siciliani, and Straume (2012).

[14] In 2010, 96% of French households were covered by supplementary health insurance.

and stable during our period of study (the years 2005 to 2008), accounting for only 2.9%, 3.1%, 3.1%, and 3% of total hospital expenditures during these four successive years.

Data The empirical analysis relies on two administrative sources: *Programme de Médicalisation des Systèmes d'Information* and *Statistique Annuelle des Établissements de santé*. Both sources are based on mandatory reporting by each and any hospital in France, and therefore are exhaustive. The former contains all patient admissions in medical, surgical and obstetrics departments, providing in particular the patient home address and the DRG to which the patient stay has been assigned. The latter provides information about equipment, staff and bed capacity. We also collected demographic variables at the French *département* level,[15] in particular average income and population stratified by age and gender.

The period of study is the phase-in period of the reform, namely the four years 2005 to 2008. The geographic area under consideration is mainland France, i.e., metropolitan France at the exclusion of Corsica. We take the most comprehensive view of hospital activity. We only remove errors (invalid time or zip codes), missing values, and outliers from the data. We select patients coming from home because we use the patients' home addresses. We drop observations with travel time above 150 minutes because they may correspond to patients who need surgery while on vacation far from their home. Overall, we keep 98% of all surgery admissions. Our working sample contains about 5.2 million admissions per year.

Market and firms The present study restricts attention to surgery, which accounts for about 35% of hospital acute-care admissions in medical, surgical and obstetrics departments. As regards surgery, the structure of the hospital industry has remained constant over the period of study. Our data set includes all hospitals that offer surgery services in mainland France, namely $1,153$ hospitals, among which 477 are government-owned, 111 are private nonprofit hospitals, and 565 are private, for-profit clinics, see Table 2. Hence there are 588 $\mathcal{S}$-hospitals and 565 $\mathcal{N}$-hospitals. The surgery bed capacity of a government-owned hospital is generally slightly higher than that of for-profit clinic (101 versus 80), and government-owned hospitals account for a higher share of the total capacity at the national level than for-profit clinics (48% versus 45%). The 111 private nonprofit

[15] Mainland France is divided in 94 administrative *départements* with about 650,000 inhabitants on average.

hospitals are generally smaller and account for the remaining 6% of the aggregate bed capacity. A for-profit clinic has generally much more patient admissions than a government-owned hospitals (5,500 versus 4,000 in 2008), and all for-profit clinics together represent about 60% of all surgery admissions.

Table 2: Summary statistics at the hospital level

	Subject to the reform hospitals ($\mathcal{S}$)						Not subject ($\mathcal{N}$)		Total	
	Gov.-owned		Private nonprofit		Together		For-profit clinics		Total	
# of hospitals	477		111		588		565		1,153	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
# stays in 2005	3,763.1	(5,250.1)	2,181.2	(2,334.5)	3,464.5	(4,874.1)	5,459.7	(3,570.0)	4,442.2	(4,397.8)
# stays in 2006	3,855.8	(5,416.9)	2,232.5	(2,449.3)	3,549.3	(5,032.1)	5,531.6	(3,608.3)	4,520.7	(4,501.1)
# stays in 2007	3,896.9	(5,493.6)	2,293.6	(2,511.9)	3,597.0	(5,107.6)	5,446.5	(3,597.8)	4,503.3	(4,526.1)
# stays in 2008	4,032.6	(5,737.1)	2,393.2	(2,627.9)	3,725.9	(5,332.7)	5,382.2	(3,638.0)	4,537.6	(4,653.6)
# stays (2008 - 2005)	273.8	(662.5)	208.0	(551.3)	261.4	(643.0)	-77.4	(1130.6)	95.4	(930.2)
			Beds and unused capacity in 2004							
# beds	100.7	(153.2)	58.1	(60.1)	92.7	(141.5)	80.4	(46.6)	86.6	(105.3)
Unused Capacity	33.9	(50.9)	25.9	(27.1)	32.4	(47.4)	34.6	(21.2)	33.5	(36.7)
			Exposure to competition in 2004							
Central^{N}	0.220	(0.351)	0.383	(0.467)	0.250	(0.380)	0.314	(0.423)	0.282	(0.404)
Central^{S}	0.154	(0.246)	0.323	(0.310)	0.185	(0.267)	0.261	(0.291)	0.223	(0.281)
				Debt ratio						
Debt / total assets	0.357	(0.162)	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Financial information available for 441 government-owned hospitals only.
Unused capacity in thousands bed-days.

Reduced-form evidence From Table 2, it is easy to check that $\mathcal{S}$-hospitals accounted for 39.8% (41.9%) of all surgery admissions in 2005 (2008). The differential increase (double difference) amounted to $197,000$ stays. Table 3 shows an increase in volumes of 24.2 stays per hospital, clinical department and year at $\mathcal{S}$-hospitals relative to $\mathcal{N}$-hospitals between 2005 and 2008.

Table 3: Difference in differences (per hospital and clinical department)

		2005		2008		$2008-2005$	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Number of stays	Not subject to the reform ($\mathcal{N}$)	399.5	(8.2)	409.4	(8.7)	-4.2	(2.5)
	Subject to the reform ($\mathcal{S}$)	256.2	(6.5)	279.9	(7.1)	20.0	(1.3)
	$\mathcal{S}-\mathcal{N}$	-143.2	(10.4)	-129.5	(11.2)	24.2	(2.7)

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Number of stays per hospital, clinical dept, year.

4.4 Data aggregation

We believe that the notion of clinical department is better adapted than the DRG classification to describe hospital choice. Indeed, there are hundreds of diagnosis-related groups and the classification is abstract from the perspective of patients and general practitioners (GP) who address them to hospitals. A GP may trust a particular surgeon, medical team or service within a given hospital, and that trust generally extends beyond a narrow set of DRG codes. There are 19 clinical departments, among which orthopedics, ENT-stomatology, ophthalmology, gastroenterology, gynaecology, dermatology, nephrology and circulatory system account for 92.4% of total activity.[16] Hereafter the clinical departments are indexed by the letter g.

We use postal zip codes to represent patient and hospital locations. There are about 37,000 patient zip codes in mainland France. A zip code, therefore, is much smaller than an administrative *département*. In rural areas, several cities may share the same zip code; Paris, on the other hand, has 20 zip codes or *arrondissements*, and the second and third largest cities (Marseilles and Lyon) also have many zip codes.[17] Hereafter the clinical departments are indexed by the letter z.

Table 4: Summary statistics at the demand unit level

	Mean	S.D.
Number of patients	14.90	(79.46)
Number of hospitals	3.33	(4.59)
Number of demand units gzt	1,392,775	

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. A demand unit is a triple (clinical department × patient zip code × year) with at least one patient admission.
The data set contains 20,753,308 patient admissions.

To estimate the travel costs incurred by patients and the variation over time of the average utility supplied by each hospital in each clinical department, we aggregate at the (clinical department, patient location, year) level. We define "demand units" as triples gzt for which at least one patient admission occurred.

[16] The shares of each clinical department in number of surgery stays at the national level are shown in Table 13.

[17] All distances in the paper are based on the center of the corresponding zip codes, and are computed with INRA's Odomatrix software.

The data set contains about 1.4 million such demand units, see Table 4.

For each demand unit gzt, we observe the number n_{ghzt} of admissions for any hospital h that receives at least one patient from that unit. The total number of admissions in a demand unit is therefore: $n_{gzt} = \sum_h n_{ghzt}$. As shown in Table 4, the average unit has 14.9 admissions in 3.3 distinct hospitals.

Table 5: Summary statistics at the (hospital, demand unit) level

	Mean	S.D.	min	q10	q25	q50	q75	q90	max
Market share	0.322	(0.523)	0.000	0.038	0.120	0.278	0.474	0.667	1
Time (in minutes)	27.2	(54.7)	0.0	0.0	9.5	22.0	37.5	59.5	149.5
Number of observations $ghzt$					4,640,991				

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. 4,640,991 (hospital × clinical department × patient zip code × year) observations weighted by the number of surgical discharges n_{hzgt}.

The local share of hospital h in the demand unit gzt is $\hat{s}_{ghzt} = n_{ghzt}/n_{gzt}$. In Table 5, we present the distribution of local shares and travel time per admission (each (g, h, z, t) observation is weighted by the corresponding number of admissions n_{ghzt}). For less than 10% of the admissions, a single hospital serves all patients from the demand unit. The minimum local market share in the data is positive but lower than .0005. For more than 75% of admissions, the hospital and patient zip codes are different. The median and mean travel time between patient and hospital for an admission are respectively 22 and 27 minutes. Overall, the dispersion indicators (standard deviation, interquartile ratio) are relatively high for both local shares and travel times.

5 Econometric model

To empirically study the transmission and propagation of the regulatory shock described above, we infer the utility changes from the evolution of patient flows as reimbursement incentives were being strengthened for $\mathcal{S}$-hospitals. This step requires a structural model of hospital choice that we present below. To estimate the travel costs incurred by patients, we develop in Section 5.1 a novel method that avoids choice set restrictions or normalization assumptions. Finally, in Section 5.2, we place structure on the variations over time of the utilities supplied by the hospitals.

Our econometric specification of patient demand is consistent with the additive model (1). For patient i living at location (zip code) z and seeking surgery care in clinical department g at date t, the net utility from undergoing treatment in hospital h is

$$U_{ighzt} = u_{ght} - \alpha d_{hz} + \xi_{ghzt} + \varepsilon_{ighzt}, \tag{12}$$

where d_{hz} denotes the travel time between patient home and hospital location.[18] The first term in (12), u_{ght}, is the average utility supplied by hospital h at year t in each clinical department g. The last two terms are statistical disturbances.

The perturbations ξ_{ghzt} reflect deviations from mean attractiveness in patient area z. The perception of a hospital's attractiveness may indeed vary across patient locations, due to historical, administrative or economic relationships between the patient city and the hospital city, or for any other reason, e.g., general practitioners practicing in a given area may have connections to a particular hospital and tend to refer their patients to that hospital.

Finally, the term ε_{ighzt} is an idiosyncratic perturbation at the patient level. As is standard in the literature, we assume that ε_{ighzt} is an i.i.d. extreme value error term, which yields the theoretical local market shares:

$$s_{ghzt} = \frac{e^{-\alpha d_{hz} + u_{ght} + \xi_{ghzt}}}{\sum_k e^{-\alpha d_{kz} + u_{gkt} + \xi_{gkzt}}}, \tag{13}$$

where the denominator includes all hospitals in mainland France.[19] Identification is achieved by exclusion restrictions. We assume that the disturbances ξ_{ghzt} are orthogonal to the industry configuration (especially firms' locations and capacities) and to a set of control variables, see the sufficient orthogonality conditions (18) and (24) below. The industry configuration is essentially given by history: it has been decided several decades before the period of study and remains extremely stable over time.

5.1 Estimation of travel costs

Two related issues about individual choice sets and market definition are critical for demand estimation. First, as is standard in the literature, we do not consider the option of not receiving surgery care, and do not seek to guess the size of

[18] We also include the square of travel time in an alternative specification. We have also estimated models where the parameter α depends on the year and on the clinical department.

[19] The identification issue in Footnote 7 is not present here: the level of α is identified by the normalization of the variance of the ε_{ighzt}'s.

the potential demand –a parameter known to affect the estimates (Nevo, 2000). Following Tay (2003), Ho (2006) or Gowrisankaran, Lucarelli, Schmidt-Dengler, and Town (2011), we estimate the hospital choice model based on hospitalized patients, i.e., conditional on hospital admission. This is why only differences in attractiveness across hospitals are identified, hence the identifiability restrictions presented above.

Second, and more importantly, we depart from the many existing studies that restrict patient choice sets, typically by defining geographic markets based on administrative boundaries (e.g., counties or states) or as the area within a given radius from the patient's home or from a main city's center. For instance, Kessler and McClellan (2000), Tay (2003), Ho (2006), and Ho and Pakes (2014) assume a maximum threshold for the distance that patients consider traveling to visit a hospital, and then check for the robustness of the results to the chosen threshold. In a similar spirit, Gowrisankaran, Lucarelli, Schmidt-Dengler, and Town (2013) define, for each patient location, an "outside good" as the set of all hospitals outside of a given radius and normalize the patient net utility for that good to zero. This leads to the standard Logit regression:

$$\ln s_{ghzt} - \ln s_{g0zt} = -\alpha d_{hz} + u_{ght} + \xi_{ghzt}. \tag{14}$$

This method has the advantage of being easy to explain and to implement, and for this reason we use it as a benchmark. Yet the normalization of the outside good's utility is not consistent with the definition of patient utility, equation (12). Furthermore, it generically implies a discontinuity in the patient net utility. As the distance to hospital rises, patient utility first linearly decreases, then brutally switches to zero when crossing the chosen cutoff radius. The discontinuity, which might well be *upwards* in some instances, is hard to justify. Finally, the estimation of (14) is based only on those observations with $s_{ghzt} > 0$. If a patient located at zip code z gets treated in a distant hospital h, it might be because ξ_{ghzt} is large at that patient location, suggesting that, conditional on $s_{ghzt} > 0$, the variables d_{hz} and ξ_{ghzt} might be positively correlated. Such a correlation would generate a downward bias in the estimation of α. The researcher would mistakenly believe that patients do not dislike distance very much while in fact ξ_{ghzt} is high when hospital h and zip code z are far apart.

We now suggest an alternative method that partially addresses the above concerns.[20] We start by choosing a reference hospital $h^{\text{ref}}(z)$ in each zip code z. We use below the following definitions for that reference hospital: (i) the hospital with the highest number of surgery beds in the patient's administrative *département*; (ii) the hospital in $\mathcal{S}$ with the highest number of surgery beds in the patient's *département*; (iii) the hospital in $\mathcal{N}$ with the highest number of surgery beds in the patient's *département*.[21]

We observe how the patient flows at the reference hospitals and the competing hospitals evolve over time. We can see whether the former gain (lose) market shares from (to) the latter by looking at the difference

$$\ln s_{ghzt} - \ln s_{gh^{\text{ref}}(z)zt} = -\alpha[d_{hz} - d_{h^{\text{ref}}(z)z}] + [u_{ght} - u_{gh^{\text{ref}}(z)t}] + [\xi_{ghzt} - \xi_{gh^{\text{ref}}(z)zt}]. \quad (15)$$

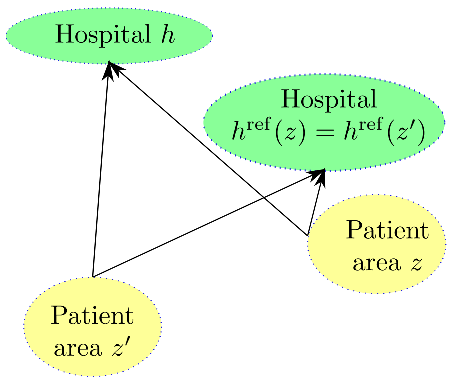


Figure 2: Double difference (in the spatial dimension) estimator

Consider now the set of all zip codes z that send patients to their reference hospitals $h^{\text{ref}}(z)$ and to another hospital h. Figure 2 shows two such zip codes, z and z'. The utility difference $u_{ght} - u_{gh^{\text{ref}}(z)t}$ is constant in this set and is eliminated by a within-transformation in the z dimension:

$$W^z \ln \frac{s_{ghzt}}{s_{gh^{\text{ref}}(z)zt}} = -\alpha W^z[d_{hz} - d_{h^{\text{ref}}(z)z}] + v_{ghzt}, \quad (16)$$

[20]A complete treatment of the selection issue is outside the scope of the present study. For recent research on this difficult problem, see Gandhi, Lu, and Shi (2014).

[21]The three definitions of the reference hospital are different as the largest hospital in the *département* belongs to the subset $\mathcal{S}$ for 70 *départements* and to the subset $\mathcal{N}$ for 24 *départements*. See also Footnote 15.

with $v_{ghzt} = W^z \left(\xi_{ghzt} - \xi_{gh^{\text{ref}}(z)zt}\right)$. The within-operator is defined as

$$W^z x_{ghzt} = x_{ghzt} - \frac{1}{|\mathcal{Z}_{hh^{\text{ref}}(z)}|} \sum_{z' \in \mathcal{Z}_{hh^{\text{ref}}(z)}} x_{ghz't}, \tag{17}$$

where $\mathcal{Z}_{hh^{\text{ref}}(z)}$ is the set of zip code locations having a positive number patients admitted in hospitals h and $h^{\text{ref}}(z)$. The orthogonality conditions

$$\mathbb{E}\left(\xi_{ghzt} \,|\, d_{kz'}\right) = 0, \tag{18}$$

for all g, h, z, t, k, z' are sufficient to guarantee strict exogeneity in (16).[22] Under these sufficient conditions, the parameter α is identified from variations of local shares and distances in the spatial dimension.

When presenting the results, we indicate below the number of pairs $(h, h^{\text{ref}}(z))$ and the average number of zip codes per pair used for estimation. The direction of a potential selection bias is more ambiguous for equation (16) than it is for equation (14), because the possible positive correlation between d_{hz} and ξ_{hz} holds for both h and $h^{\text{ref}}(z)$, hence the effect on the differences $d_{hz} - d_{h^{\text{ref}}(z)z}$ and $\xi_{hz} - \xi_{h^{\text{ref}}(z)z}$ is *a priori* unclear. Also, we note that under this "triangulation" method, the identification of α comes from the z dimension, and therefore it is possible to estimate α for each clinical department and each year separately.

Finally, as mentioned in Section 4.4, we compute the dependent variables in the estimating equations (15) by using the empirical counterparts of the local market shares, i.e., $\hat{s}_{ghzt} = n_{ghzt}/n_{gzt}$. The quality of the approximation of the theoretical share s_{ghzt} depends on the value of n_{gzt}, as noted by Berry, Levinsohn, and Pakes (1995).[23] It is therefore important to check that the results are robust to the exclusion of demand units gzt for which n_{gzt} is small.

5.2 Utility changes

We specify the utility offered by hospital h for clinical department g at date t as

$$u_{ght} = \beta^N_{ht} N_h + \beta^S_{ht} S_h + \gamma X_{ht} + A_{gt} + B_{gh}, \tag{19}$$

[22] The orthogonality conditions (18) actually need to hold only for $k = h^{\text{ref}}(z)$.

[23] In their application, there is one single demand unit whose size is on the order of 100 million, hence the variance due to the consumer sampling process is negligible. This is not necessarily the case here for small demand units.

where N_h and S_h are dummy variables for h being a $\mathcal{N}$-hospital and a $\mathcal{S}$-hospital. The parameters β_{ht}^N and β_{ht}^S therefore represent the evolution of the utilities supplied by hospitals h in $\mathcal{N}$ and $\mathcal{S}$. We include clinical department-hospital fixed effects B_{gh} to account for the hospital reputation in each clinical department. We therefore identify only *changes in* attractiveness and normalize the parameters β_{ht}^N and β_{ht}^S to zero at the beginning of the phase-in period, i.e., $\beta_{h,05}^N = \beta_{h,05}^S = 0$. We also include time-varying, hospital-specific, exogenous variables X_{ht} to control for the evolution of local demand: population density, average income as well as age and gender stratification, all evaluated in the administrative *département* where the hospital is located. Finally, to control for national trends in the utilization of hospital care, we include clinical department-time fixed effects A_{gt}.

Next we place structure on the parameters β_{ht}^N and β_{ht}^S to explain utility variations between and within each of the two groups $\mathcal{N}$ and $\mathcal{S}$:

$$\begin{array}{rcccccccc} \beta_{ht}^N & = & & & \beta_t^{NC}\text{UC}_{h,04} & + & \beta_t^{NS}\text{Central}_h^S & + & \beta_t^{NN}\text{Central}_h^N \\ \beta_{ht}^S & = & \beta_t^{S0} & + & \beta_t^{SC}\text{UC}_{h,04} & + & \beta_t^{SS}\text{Central}_h^S & + & \beta_t^{SN}\text{Central}_h^N, \end{array} \tag{20}$$

where the centrality indicators are constructed according to (11). For identification reasons, all the parameters are normalized to zero at the first year of the period, $t = 2005$.[24] Because $N_h + S_h = 1$ and time fixed effects are included in (19), we do not interact time with the dummy variable N_h. In other words, we allow for different trends for hospitals subject and not subject to the reform.

We let utility changes depend on the firms' unused capacity (UC) the year before the beginning of the phase-in period. We have argued in Section 3.3 that higher amounts of unused capacities are associated with stronger transmission for $\mathcal{S}$-hospitals because those capacities make it easier for the hospitals to react to the newly created incentives. We have also noticed that large unused capacities are also associated with lower slopes of reaction functions for $\mathcal{N}$-hospitals because they weaken the forces pushing towards strategic complementarity. Then, relying on a simplified linear model, we have found the effects of capacities on responses that are reported on line A of Table 1. The above intuitions translate into the signs of parameters β^{NC} and β^{SC} in (20) that are reported on line A of Table 6.

More importantly, we let utility changes depend on the hospital competitive environment, namely, the proximity and unused capacities of neighboring hospitals as encompassed in the centrality indicators. Based on the same simplified model,

[24] In some specifications, we let the various parameters β depend on the clinical department g.

Table 6: Impact of centrality indicators on utility changes

	Under strategic complementarity		Under strategic substitutability	
	$h \in \mathcal{S}$	$h \in \mathcal{N}$	$h \in \mathcal{S}$	$h \in \mathcal{N}$
	(1)	(2)	(3)	(4)
A. Own unused capacity	$\beta_t^{SC} > 0$	$\beta_t^{NC} < 0$	$\beta_t^{SC} > 0$	$\beta_t^{NC} < 0$
B. $\mathcal{N}$-Centrality	$\beta_t^{SN} < 0$	$\beta_t^{NN} < 0$	$\beta_t^{SN} > 0$	$\beta_t^{NN} > 0$
C. $\mathcal{S}$-Centrality	$\beta_t^{SS} > 0$	$\beta_t^{NS} > 0$	$\beta_t^{SS} < 0$	$\beta_t^{NS} < 0$

Note: The above expected signs, which parallel those reported in Table 1, apply to the parameters in the baseline specification (20). See the note below Table 1 for interpretations.

we have found in Section 3 that under strategic complementarity the proximity and unused capacity of $\mathcal{S}$-hospitals ($\mathcal{N}$-hospitals) magnifies (attenuates) hospital responses, and that these results are reversed under strategic substitutability. The intuition is that $\mathcal{S}$-hospitals with much unused capacities react strongly to the new incentives (transmission effect) and that these strong responses, under strategic complementarity, propagate to the industry. On the contrary, the proximity of $\mathcal{N}$-hospitals with much unused capacities, which are relatively inert, tends to attenuate the response of nearby hospitals. The results are reversed under strategic substitutability. The corresponding predictions for the signs of parameters β^{NN}, β^{NS}, β^{SN}, and β^{SS} appearing in (20) are reported on lines B and C of Table 6.

Specification of centrality indicators We define the function Φ of distance to and unused capacity of competitors in (11) as $\Phi(d, \mathrm{UC}) = \exp(-\alpha d).\mathrm{UC}/1000$, which yields the following expressions for the centrality indicators:

$$\mathrm{Central}_h^S = \sum_{k \neq h, k \in \mathcal{S}} e^{-\alpha d_{hk}} \mathrm{UC}_{k,04}/1000 \quad (21)$$

$$\mathrm{Central}_h^N = \sum_{k \neq h, k \in \mathcal{N}} e^{-\alpha d_{hk}} \mathrm{UC}_{k,04}/1000. \quad (22)$$

Our measure of unused capacity, $\mathrm{UC}_{k,04}$, is the difference between the maximal and the actual number of patient nights prior to the reform (i.e., in year 2004). The maximal number of beds times is computed as the hospital surgery bed capacity multiplied by 366 nights. The above sums are computed for *all* hospitals $k \neq h$ in mainland France. For each hospital h, we count the amount of unused capacity in 2004 for all hospitals (separately in $\mathcal{S}$ and in $\mathcal{N}$) weighted by an exponentially decreasing function of the travel time to hospital h. Travel times are expressed in minutes. We set the parameter α to .04, our preferred estimate of patient travel costs based on the triangulation method explained in Section 5.1.[25] It follows that 1,000 beds 25 minutes away from a hospital have a contribution of $\exp(-1) \approx .368$ to the corresponding centrality indicator.

The centrality indicators reflect the exposure to competition from $\mathcal{S}$-hospitals and $\mathcal{N}$-hospitals. From Table 2, we see that in the sense of these indicators competition from $\mathcal{N}$-hospitals is on average slightly stronger than competition from $\mathcal{S}$-hospitals (.282 compared to .223). We can also quantify intra-sector and inter-sector competition, where sectors are defined by legal status (nonprofit for $\mathcal{S}$-hospitals, for-profit for $\mathcal{N}$-hospitals): the mean values .185 and .314 reflect intra-sector competition (between respectively $\mathcal{S}$-hospitals and $\mathcal{N}$-hospitals), while the mean values .250 and .261 measure how hospitals in one sector are exposed to competition from hospitals of the other sector, i.e., inter-sector competition. We observe that on average $\mathcal{S}$-hospitals face less competition (from both sectors) than $\mathcal{N}$-hospitals. Finally, the inspection of standard deviations shows that the centrality indicators exhibit quite large variations across hospitals.

Estimation The relative changes in the gross utilities supplied by the hospitals are identified in the time dimension, while absolute utility levels remain unidentified. First-differencing equation (15) between year t and year 2005, we get

$$\ln \frac{s_{ghzt} / s_{ghz,05}}{s_{gh^{\text{ref}}(z)zt} / s_{gh^{\text{ref}}(z)z,05}} = \left(u_{ght} - u_{gh,05}\right) - \left(u_{gh^{\text{ref}}(z)t} - u_{gh^{\text{ref}}(z),05}\right) + w_{ghzt}.$$

[25] Because the data is extremely rich in the spatial dimension, the parameter α is estimated with a very high precision, see Section 6.

Using the specification for the offered utilities presented in (19) and (20), we obtain the following estimating equations for the parameters appearing in Table 6:

$$\begin{aligned}
\ln \frac{s_{ghzt}/s_{ghz,05}}{s_{gh^{\text{ref}}(z)zt}/s_{gh^{\text{ref}}(z)z,05}} &= (u_{ght} - u_{gh,05}) - \left(u_{gh^{\text{ref}}(z)t} - u_{gh^{\text{ref}}(z),05}\right) + w_{ghzt} \\
&= \beta_t^{S0}\left[S_h - S_{h^{\text{ref}}(z)}\right] \\
&+ \beta_t^{SC}\left[S_h \text{ UC}_h - S_{h^{\text{ref}}(z)} \text{ UC}_{h^{\text{ref}}(z)}\right] \\
&+ \beta_t^{NC}\left[N_h \text{ UC}_h - N_{h^{\text{ref}}(z)} \text{ UC}_{h^{\text{ref}}(z)}\right] \\
&+ \beta_t^{SS}\left[S_h \text{ Central}_h^S - S_{h^{\text{ref}}(z)} \text{ Central}_{h^{\text{ref}}(z)}^S\right] \\
&+ \beta_t^{SN}\left[S_h \text{ Central}_h^N - S_{h^{\text{ref}}(z)} \text{ Central}_{h^{\text{ref}}(z)}^N\right] \\
&+ \beta_t^{NS}\left[N_h \text{ Central}_h^S - N_{h^{\text{ref}}(z)} \text{ Central}_{h^{\text{ref}}(z)}^S\right] \\
&+ \beta_t^{NN}\left[N_h \text{ Central}_h^N - N_{h^{\text{ref}}(z)} \text{ Central}_{h^{\text{ref}}(z)}^N\right] \\
&+ \gamma\left[\left(X_{ht} - X_{h^{\text{ref}}(z)t}\right) - \left(X_{h,05} - X_{h^{\text{ref}}(z),05}\right)\right] \\
&+ w_{ghzt}, \qquad (23)
\end{aligned}$$

where $w_{ghzt} = (\xi_{ghzt} - \xi_{ghz,05}) - (\xi_{gh^{\text{ref}}(z)zt} - \xi_{gh^{\text{ref}}(z)z,05}), t > 2005$. Strict exogeneity holds if the disturbances ξ_{ghzt} are orthogonal to the explanatory variables:

$$\mathbb{E}\left(\xi_{ghzt} \mid S_k, \text{UC}_{k,04}, \text{Central}_k^N, \text{Central}_k^S, X_{kt}\right) = 0, \qquad (24)$$

for all g, h, k, t, z. Whether hospitals are subject to the regulatory shock depends on their for-profit versus nonprofit status, which has been fixed for years. We thus consider the dummy variable S_k as exogenous over the relatively short period of study. Similarly, the unused capacities and centrality indicators, as well as the financial ratios used in an extended model, are all evaluated prior to the regulatory shock (in 2004), and are assumed to be orthogonal to unobserved factors that might affect demand or costs after 2005. In sum, our estimation strategy consists in inferring the effect of the variables of interest (own unused capacity, proximity of $\mathcal{S}$-hospitals, etc.) from the behavior of double differences $(u_{ht} - u_{ht_0}) - (u_{kt} - u_{kt_0})$. In that sense closely parallels the theoretical analysis of Section 3.

Revenue effects Finally, in an extension, we let utility changes for $\mathcal{S}$-hospitals depend also on their debt ratio (evaluated before the beginning of the phase-in period). If more indebted hospitals have a higher marginal utility for revenue, those hospitals should respond more vigorously to the reform, relative to other less indebted $\mathcal{S}$-hospitals, see Appendix C. Due to data limitations, we observe this financial ratio for government-owned hospitals only. We therefore have first to distinguish $\mathcal{S}$-hospitals according to their ownership status. Then we can compare the responses of more or less indebted government-owned hospitals. We also estimate a model where utility changes depend furthermore on ownership status and, among government-owned hospitals, on debt ratio. The estimating equation is derived in the same way as above.

6 Results

As discussed in Section 5.1, we start by estimating a Logit regression with an "outside good" defined, for each patient location, as the set of hospitals outside of a given radius. In light of the theoretical analysis of Section 3, the results obtained under this simple specification strongly suggest that the utilities supplied to patients are strategic complements. We then implement our preferred estimation method, based on double differences in the spatial and time dimensions. The results confirm the qualitative insights from the simple Logit model and allow to quantity the strength of network interactions.

6.1 Model with "outside good"

Table 7 reports the estimation results for equation (14) with the outside good defined as the set of hospitals outside of a one-hour cutoff radius. The first line of the table shows an estimated travel disutility cost of .025 per minute, which we discuss in greater detail below. Regarding utility variations, the first column shows the estimation results for the baseline specification (19)-(20) while the second column includes the ownership status of $\mathcal{S}$-hospitals and the debt ratio of government-owned hospitals.

Panels A1 to C2 of Table 7 are labeled as the corresponding cells of Tables 1 and 6. The reported signs are consistent with the left part of those tables, i.e., with strategic complementarity. More specifically, the impact of competition on hospital responses is shown in panels B1 to C2. We find that the proximity and unused capacities of $\mathcal{S}$-hospitals ($\mathcal{N}$-hospitals) is associated with stronger (weaker) increases in the utility provided to patients, both for $\mathcal{N}$-hospitals and in $\mathcal{S}$. This suggests that the utilities supplied by the hospitals are strategic complements. The results are statistically significant for all parameters in panels B1 to C2 under the baseline specification. We obtain less significance when the debt ratio is included in the regression equation. Moreover, according to the estimates reported in panel F, more indebted government-owned hospitals do not appear to have responded more vigorously to the reform.

Regarding the effect of own unused capacities, the theoretical predictions are not rejected by the data. Panel A1 shows that, as expected from theory, among $\mathcal{S}$-hospitals those with larger margins of unused capacity prior to the regulatory shock have responded more vigorously to the shock. For $\mathcal{N}$-hospitals, however, the effect of own unused capacities is not statistically significant.

6.2 Model without "outside good"

We now implement the method based on double differences relative to reference hospitals, i.e., we estimate travel costs and utility changes from (16) and (23).

Table 7: Using distant hospitals as an "outside good"

Travel time	-0.025***	-0.025***	
	(0.000)	(0.000)	
S × UC_{2004} × 2006	0.123***	0.104***	
	(0.031)	(0.031)	
S × UC_{2004} × 2007	0.075**	0.044	Panel A1
	(0.035)	(0.037)	
S × UC_{2004} × 2008	0.079**	0.077**	
	(0.032)	(0.033)	
N × UC_{2004} × 2006	-0.160	-0.160	
	(0.135)	(0.138)	
N × UC_{2004} × 2007	0.022	0.027	Panel A2
	(0.149)	(0.151)	
N × UC_{2004} × 2008	0.005	0.003	
	(0.173)	(0.177)	
S × $Central^N$ × 2006	-0.079***	0.005	
	(0.027)	(0.019)	
S × $Central^N$ × 2007	-0.102***	-0.018	Panel B1
	(0.029)	(0.020)	
S × $Central^N$ × 2008	-0.119***	-0.007	
	(0.031)	(0.023)	
N × $Central^N$ × 2006	-0.053**	0.004	
	(0.023)	(0.014)	
N × $Central^N$ × 2007	-0.105***	-0.021	Panel B2
	(0.028)	(0.017)	
N × $Central^N$ × 2008	-0.081***	0.009	
	(0.031)	(0.021)	
S × $Central^S$ × 2006	0.118***	0.056	
	(0.037)	(0.050)	
S × $Central^S$ × 2007	0.150***	0.164***	Panel C1
	(0.039)	(0.052)	
S × $Central^S$ × 2008	0.212***	0.146***	
	(0.042)	(0.056)	
N × $Central^S$ × 2006	0.097***	0.054	
	(0.033)	(0.034)	
N × $Central^S$ × 2007	0.183***	0.160***	Panel C2
	(0.038)	(0.040)	
N × $Central^S$ × 2008	0.184***	0.139***	
	(0.043)	(0.046)	
S × 2006	0.023***		
	(0.008)		
S × 2007	0.053***		Panel D
	(0.009)		
S × 2008	0.066***		
	(0.010)		
Pri-owned × 2006		0.047***	
		(0.014)	
Pri-owned × 2007		0.072***	Panel E1
		(0.016)	
Pri-owned × 2008		0.104***	
		(0.017)	
Gov-owned × 2006		0.021*	
		(0.012)	
Gov-owned × 2007		0.057***	Panel E2
		(0.013)	
Gov-owned × 2008		0.046***	
		(0.014)	
Gov-owned × debt $ratio_{2004}$ × 2006		-0.016	
		(0.022)	
Gov-owned × debt $ratio_{2004}$ × 2007		-0.026	Panel F
		(0.025)	
Gov-owned × debt $ratio_{2004}$ × 2008		0.025	
		(0.025)	
Hospital-year controls	Yes	Yes	
Clinical dept-year effects	Yes	Yes	
Observations	2852783	2627296	
R^2	0.275	0.281	

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Notes: A market is defined as the set of hospitals within 60' travel time.
Controls include density, income, population of h's *département*. Robust standard errors in parentheses.
Panel labels in the right column (from A1 to C2) show the correspondence with the cells of Tables 1 and 6.

Travel costs Table 8 reports the disutility cost of travel time for the three choices of reference hospital. The number of observations for which the difference $\ln s_{ghzt} - \ln s_{gh^{\text{ref}}(z)zt}$ is defined at the left-hand side of the triangulation equation (16) varies across columns, i.e., with the definition of the reference hospital. We find an estimated cost α of about .040 per minute, highly significant because of the very rich variation in the spatial dimension.[26] The estimate found with the outside good approach, .025, might therefore be biased downwards as suggested in Section 5.1. In Table 9, we reiterate the estimation of travel costs after dropping hospital pairs $(h, h^{\text{ref}}(z))$ for which the cardinal of the set $\mathcal{Z}_{hh^{\text{ref}}(z)}$ defined below (17) is lower than or equal to various thresholds (for those pairs only few zip-codes can be used for triangulation). The estimate of α appears to be extremely robust to the chosen threshold.

Table 8: Travel costs

Reference hospital	(1)	(2)	(3)
Travel time	-0.040***	-0.040***	-0.042***
	(0.000)	(0.000)	(0.000)
# of pairs $(h, h^{\text{ref}}(z))$	13035	13036	13007
Average # of zip codes per pair	18.5	18.5	18.3
Observations	2758304	2650617	2319871
R^2	0.320	0.325	0.325

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital:
(1) the largest in the *département*
(2) the largest nonprofit in the *département*
(3) the largest for-profit in the *département*
Robust standard errors in parentheses.

Strategic interactions Returning to the study of utility variations, Table 10 presents the estimation results for the baseline specification (19)-(20). The results shown in panels A1 to C2 coincide remarkably with the expected effects reported in the corresponding cells of Tables 1 and 6, with high levels of statistical significance. In particular, panels B1 to C2, which allow to discriminate between strategic complementarity and strategic substitutability, strongly support the former hypothesis. The results for these four panels are robust to the definition of the reference hospital (columns 1 to 3 of Table 10). They hold when we drop all demand units with less than 100 inpatient admissions (column 4), suggesting

[26]Estimating travel costs separately for each of the eight main clinical departments shown in Table 13 yields estimates comprised between .035 and .046. We have also checked the travel cost estimates vary very little over the four years of the period of interest.

Table 9: Travel costs, dropping hospital pairs with small number of zip codes

Threshold	2	5	10	20	50	100
Travel time	-0.040***	-0.040***	-0.040***	-0.041***	-0.040***	-0.040***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	2718684	2629416	2507354	2281277	1772162	1211473
R^2	0.320	0.320	0.320	0.321	0.308	0.267

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital: the largest in the *département*
Robust standard errors in parentheses.
When the threshold equals 10, we keep pairs of hospitals $(h, h^{\text{ref}}(z))$ such that at least 10 distinct zip codes send a positive number of patients in both hospitals.

that the error due to the consumer sampling process does not play any role in the qualitative results (recall Footnote 23).

As regards the effects of own unused capacity, panels A1 and A2 show statistically significant estimates that are consistent with theory. In all specifications, the average income and the population density of the administrative *département* are included in the covariates X_{ht} of equation (19). These two variables turn out to have a significantly positive effect on the utility variations.

Average relative effect of the reform The analysis developed in Section 3.2 suggests that the utility supplied to patients should increase more rapidly for $\mathcal{S}$-hospitals than for $\mathcal{N}$-hospitals, recall inequality (8). The following ratio expresses the average relative effect in terms of travel time

$$\tau_t^0 = \frac{1}{\hat{\alpha}} \left[\frac{1}{|\mathcal{S}|} \sum_{h \in \mathcal{S}} (\hat{u}_{ght} - \hat{u}_{gh,05}) - \frac{1}{|\mathcal{N}|} \sum_{k \in \mathcal{N}} (\hat{u}_{gkt} - \hat{u}_{gk,05}) \right]. \tag{25}$$

The effects A_{gt} and B_{gh} appearing in (19) cancel out in (25). We estimate the standard error of the above ratio by non-parametric bootstrap. We proceed to 200 draws with replacement from the data set at the (g,h,z,t) level, estimate (16) and (23) in each replicated sample, and compute the standard deviation of the ratio τ_t^0.

Table 11 shows that the average relative effect of the reform increases over time as hospital incentives are being gradually strengthened. After complete implementation of the reform, i.e., in year 2008, the magnitude of the effect is of little less than two minutes and is highly significant. This effect is sizable as two minutes represent about 9% of the median travel time to hospitals for surgery

Table 10: Assessing the strength of strategic interactions

Reference hospital	(1)	(2)	(3)	(4)	
S × UC_{2004} × 2006	0.143***	0.148***	0.095***	0.244***	
	(0.015)	(0.015)	(0.033)	(0.023)	
S × UC_{2004} × 2007	0.088***	0.094***	0.029	0.232***	Panel A1
	(0.016)	(0.016)	(0.034)	(0.024)	
S × UC_{2004} × 2008	0.183***	0.206***	0.117***	0.405***	
	(0.016)	(0.016)	(0.035)	(0.025)	
N × UC_{2004} × 2006	-0.743***	-0.426***	-0.237***	-1.092***	
	(0.084)	(0.100)	(0.072)	(0.144)	
N × UC_{2004} × 2007	-0.462***	-0.267***	0.133*	-0.150	Panel A2
	(0.087)	(0.103)	(0.076)	(0.152)	
N × UC_{2004} × 2008	-0.239***	-0.101	-0.008	-0.191	
	(0.091)	(0.107)	(0.082)	(0.161)	
S × $Central^N$ × 2006	-0.154***	-0.154***	-0.053*	-0.242***	
	(0.019)	(0.019)	(0.027)	(0.025)	
S × $Central^N$ × 2007	-0.096***	-0.109***	-0.068**	-0.063**	Panel B1
	(0.019)	(0.020)	(0.029)	(0.026)	
S × $Central^N$ × 2008	-0.257***	-0.277***	-0.155***	-0.279***	
	(0.020)	(0.020)	(0.030)	(0.028)	
N × $Central^N$ × 2006	-0.091***	-0.104***	-0.105***	-0.139***	
	(0.019)	(0.019)	(0.018)	(0.025)	
N × $Central^N$ × 2007	-0.148***	-0.166***	-0.125***	-0.175***	Panel B2
	(0.020)	(0.020)	(0.020)	(0.027)	
N × $Central^N$ × 2008	-0.156***	-0.194***	-0.139***	-0.201***	
	(0.021)	(0.021)	(0.021)	(0.028)	
S × $Central^S$ × 2006	0.310***	0.274***	0.124***	0.417***	
	(0.023)	(0.023)	(0.034)	(0.031)	
S × $Central^S$ × 2007	0.198***	0.197***	0.096***	0.153***	Panel C1
	(0.024)	(0.024)	(0.036)	(0.032)	
S × $Central^S$ × 2008	0.339***	0.370***	0.265***	0.349***	
	(0.025)	(0.025)	(0.038)	(0.035)	
N × $Central^S$ × 2006	0.270***	0.272***	0.198***	0.307***	
	(0.024)	(0.025)	(0.021)	(0.034)	
N × $Central^S$ × 2007	0.250***	0.276***	0.192***	0.236***	Panel C2
	(0.025)	(0.026)	(0.022)	(0.036)	
N × $Central^S$ × 2008	0.202***	0.271***	0.226***	0.201***	
	(0.026)	(0.027)	(0.023)	(0.037)	
S × 2006	-0.002	0.003	0.026***	-0.030***	
	(0.005)	(0.005)	(0.006)	(0.010)	
S × 2007	0.031***	0.035***	0.068***	0.014	Panel D
	(0.005)	(0.006)	(0.006)	(0.010)	
S × 2008	0.076***	0.076***	0.073***	0.056***	
	(0.006)	(0.006)	(0.007)	(0.011)	
Hospital-year controls	Yes	Yes	Yes	Yes	
Observations	1786346	1710208	1504927	442742	
R^2	0.005	0.003	0.005	0.012	

Source. French PMSI, individual data, 2005-2008.

Sample. 1,153 hospitals in mainland France.

Note. Reference hospital:

(1) the largest in the *département*

(2) the largest public in the *département*

(3) the largest private in the *département*

(4) the largest in the *département*, dropping demand units gzt with less than 100 patients

Robust standard errors in parentheses.

Controls include density, income, population of h's *département*.

Panel labels from A1 to C2 in the right column show the correspondence with the cells of Tables 1 and 6.

admissions. The table also shows that the estimated average relative effect is moderately sensitive to the definition of the reference hospitals, with an effect comprised between 1.6 and 2 minutes in 2008 for the three definitions. Table 12 checks that the estimated effect does not change dramatically when demand units with small numbers of patients are excluded from the sample.[27]

Table 11: Average relative effects (minutes)

Reference hospital	(1)	(2)	(3)
In 2006	0.023	-0.184	0.623
	(0.074)	(0.073)	(0.084)
In 2007	0.953	0.765	1.206
	(0.076)	(0.080)	(0.109)
In 2008	1.965	1.744	1.644
	(0.079)	(0.083)	(0.106)

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital:
(1) the largest in the *département*
(2) the largest public in the *département*
(3) the largest private in the *département*

Table 13 shows the average relative effects of the reform for each of the eight main clinical departments (that together account for more than 92% of all surgery admissions). These effects are obtained by estimating the model separately for each department, i.e., by allowing the parameters α and β_t in (16) and (23) to depend on the clinical department. We only report the average relative effects at the end of the phase-in period, i.e., in 2008. We find that those effects vary across clinical departments between 0.6 and 4.7 minutes, i.e., between 3% and 20% of the median travel time for the corresponding department. The weakest effect is found for orthopedics, the department with the largest number of admissions. By contrast, for the second largest department, stomatology, $\mathcal{S}$-hospitals increased their catchment area by 3.6 minutes –18% of the median travel time in that department– relative to $\mathcal{N}$-hospitals.

Assessing the strength of network interactions As already seen, panels B1 to C2 of Table 10 support the hypothesis that the utilities supplied by hospitals are

[27]For instance, if we consider only demand units with at least 50 patients ($n_{gzt} > 50$), the estimated effect is close to 1.4 minute.

Table 12: Average relative effect in 2008, dropping small demand units gzt

Minimum number of patients in gzt	2	5	10	20	50	100
Average relative effect in 2008 (minutes)	1.969	1.917	1.823	1.646	1.438	1.317

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital: the largest in the *département*

strategic complements. To express the intensity of strategic forces in a concrete manner, we evaluate the effect of one-standard-deviation increases in the centrality indicators. For instance, the ratio

$$\tau_t^{SN} = \frac{\hat{\beta}_t^{SN} \text{ S.D.} \left(\text{Central}^N \,|\, \mathcal{S}\right)}{\hat{\alpha}} \tag{26}$$

measures by how many minutes a one-standard-deviation increase in exposure to competition from $\mathcal{N}$-hospitals increases the response of $\mathcal{S}$-hospitals to the shock.[28] The ratios τ_t^{SS}, τ_t^{NS}, and τ_t^{NN} are similarly defined. Standard errors for these parameters are estimated by bootstrap as explained above.

Table 13: Average relative effect in 2008 (minutes), by clinical department

	Activity share (1)	Average relative effects (2)	S.E. (3)	Median time (4)	Ratio (%) (2)/(4)
Orthopedics	27.1%	0.636	(0.144)	22.5	2.8
ENT, Stomato.	13.0%	3.612	(0.216)	20.5	17.6
Ophthalmology	12.7%	1.915	(0.298)	23	8.3
Gastroenterology	11.8%	1.799	(0.214)	18.5	9.7
Gynaecology	8.5%	2.942	(0.232)	23	12.8
Dermatology	7.2%	3.494	(0.311)	20	17.5
Nephrology	7.0%	1.745	(0.313)	21	8.3
Circulatory syst.	5.1%	4.729	(0.399)	23.5	20.1
All	100.0%	1.965	(0.079)	22	8.9

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital: the largest in the *département*
Standard errors are computed by bootstrap.
Controls include density, income, population of h's *département*.

Table 14 shows that the complementarity between reimbursement incentives and strategic forces is strong. To illustrate, for a $\mathcal{S}$-hospital, a one-standard-deviation increase in exposure to competition from other $\mathcal{S}$-hospitals raises the response by 2.3 minutes, that is, by the same order of magnitude as the average relative effect; similarly, a one-standard-deviation increase in exposure to competition from $\mathcal{N}$-hospitals decreases the response by 2.4 minutes. The order of

[28] The standard deviations of the centrality indicators within each of the two subgroups $\mathcal{N}$ and $\mathcal{S}$ are found in Table 2. For instance the standard deviation appearing in (26) is .38.

Table 14: Increasing centrality indicators by one standard-deviation

Interaction	SS	NS	SN	NN
Effect in 2008 (minutes)	2.263	1.470	-2.442	-1.650
Standard error	(0.160)	(0.194)	(0.193)	(0.232)

Note. Increasing centrality indicators by one standard deviation
Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital: the largest in the *département*
Standard errors are computed by bootstrap.

magnitude of each of the two competitive effects is one third lower when the concerned hospital is a $\mathcal{N}$-hospital (respectively 1.5 minutes instead of 2.3 and -1.7 minutes instead of -2.4).

Marginal utility of revenue We use hospitals' debt ratios (debt over total assets) as proxies for their marginal utility of revenue. Again, this indicator is available in the database for (almost all) government-owned hospitals, but not for privately-owned hospitals. As shown in Table 2, debt represents 36% of assets for the average government-owned hospital, and the dispersion of the debt ratio is lower than that of the centrality indicators.[29]

Table 15 shows the estimation results for a specification that includes furthermore the ownership status of $\mathcal{S}$-hospitals and the debt ratio of government-owned hospitals. The structure of the table is the same as above, with all (but one) parameters in panels A1 to C2 being significant and of the signs announced in the corresponding cells of Tables 1 and 6. Panel F reports the effect of the financial indicator. As predicted in Appendix C, we find that a higher debt ratio before the reform is associated with a larger utility variation over the whole phase-in period of the reform, i.e., between 2005 and 2008.

Table 16 reports the estimated ratio

$$\tau_t^{SF} = \frac{\hat{\beta}_t^{SF}\ \text{S.D.}\,(\text{debt ratio}\,|\,\mathcal{S})}{\hat{\alpha}},$$

showing that a one-standard-deviation increase in the debt ratio raises the response of government-owned $\mathcal{S}$-hospitals by .4 minute, about 20% of the average relative effect of the reform.

[29]The standard deviation of the debt ratio for government-owned hospitals is .16.

Table 15: Allowing for heterogeneous marginal utilities of revenue

S × UC_{2004} × 2006	0.083***	
	(0.017)	
S × UC_{2004} × 2007	0.060***	Panel A1
	(0.018)	
S × UC_{2004} × 2008	0.150***	
	(0.018)	
N × UC_{2004} × 2006	-0.338***	
	(0.102)	
N × UC_{2004} × 2007	-0.181*	Panel A2
	(0.105)	
N × UC_{2004} × 2008	0.080	
	(0.110)	
S × $Central^N$ × 2006	-0.121***	
	(0.015)	
S × $Central^N$ × 2007	-0.091***	Panel B1
	(0.016)	
S × $Central^N$ × 2008	-0.102***	
	(0.017)	
N × $Central^N$ × 2006	-0.054***	
	(0.014)	
N × $Central^N$ × 2007	-0.134***	Panel B2
	(0.015)	
N × $Central^N$ × 2008	-0.094***	
	(0.017)	
S × $Central^S$ × 2006	0.416***	
	(0.040)	
S × $Central^S$ × 2007	0.407***	Panel C1
	(0.041)	
S × $Central^S$ × 2008	0.572***	
	(0.043)	
N × $Central^S$ × 2006	0.246***	
	(0.028)	
N × $Central^S$ × 2007	0.363***	Panel C2
	(0.029)	
N × $Central^S$ × 2008	0.328***	
	(0.030)	
Pri-owned × 2006	0.079***	
	(0.010)	
Pri-owned × 2007	0.054***	Panel E1
	(0.010)	
Pri-owned × 2008	0.041***	
	(0.010)	
Gov-owned × 2006	-0.066***	
	(0.011)	
Gov-owned × 2007	-0.019*	Panel E2
	(0.011)	
Gov-owned × 2008	-0.001	
	(0.011)	
Gov-owned × debt $ratio_{2004}$ × 2006	-0.028**	
	(0.013)	
Gov-owned × debt $ratio_{2004}$ × 2007	0.020	Panel F
	(0.014)	
Gov-owned × debt $ratio_{2004}$ × 2008	0.093***	
	(0.014)	
Hospital-year controls	Yes	
Observations	1585710	
R^2	0.003	

Source. French PMSI, individual data, 2005-2008.

Sample. 1,153 hospitals in mainland France.

Note. Reference hospital: the largest nonprofit in the *département*.

Robust standard errors in parentheses.

Controls include density, income, population of h's *département*.

Panel labels from A1 to C2 in the right column show the correspondence with the cells of Tables 1 and 6.

Table 16: Increasing debt ratio by one standard-deviation

Effect in 2008 (minutes)	0.377
Standard error	(0.056)

Source. French PMSI, individual data, 2005-2008.
Sample. 1,153 hospitals in mainland France.
Note. Reference hospital: the largest in the *département*
Standard errors are computed by bootstrap.

7 Concluding remarks

We have designed and implemented a method to empirically assess the nature and strength of strategic interactions in a spatial network when the strategic variable is not observed by the researcher. We have constructed centrality indicators based on qualitative properties of Leontief matrices, and used these indicators to quantify the role of strategic interactions in the propagation of firm-level shocks. Observing firm-level activity after the shocks realize, we have inferred the evolution of the utilities provided by firms to consumers.

In the case of the hospital industry, the utilities supplied to patients are unobserved. The set of all hospitals can be thought of as a network, i.e., as a description of paths along which patients flow. As noted by Kessler and McClellan (2000), patient flows are outcomes of the competitive process. By modeling the evolution of these flows, we are able to assess the extent to which hospitals adjusted the utilities provided to patients in response to an asymmetric regulatory shock.

The present study complements the vast literature that relies on clinical quality indicators. For instance, to investigate how hospital quality has been affected by increased patient choice in the United Kingdom, Gaynor, Propper, and Seiler (2012) construct a measure of hospital mortality that is corrected for patient selection. Gaynor and Town (2012) and Gaynor, Ho, and Town (forthcoming) survey numerous studies that use observed proxies for quality.[30] Our method offers an alternative route when no such data is available. In our framework, the endogenous selection of patients into hospitals is the primary object of interest,

[30] See, e.g., Cutler (1995), Shen (2003), Cooper, Gibbons, Jones, and McGuire (2011), Propper (2012), Varkevisser, van der Geest, and Schut (2012). Our findings about the nature of competition are reminiscent of Gravelle, Santos, and Siciliani (2014) who examine the strategic properties of hospital quality using mortality, complication, and readmission rates as well as reported indicators of patients' experience.

together with the patterns of shock propagation.

The proposed methodology makes it possible to estimate the effect of financial incentives and imperfect competition in an industry with spatial differentiation. In the case of the hospital industry, we have documented a strong complementarity between payment incentives and competition forces, shedding light on policy discussions about the respective roles of competition and regulation. First, we have shown that government-owned and other nonprofit hospitals ("$\mathcal{S}$-firms"), when properly stimulated by financial incentives, have been able to take market shares away from for-profit hospitals ("$\mathcal{N}$-firms").[31] Second, we have highlighted the role of inter-sector competition in propagating incentives across hospitals: for-profit hospitals exposed to competition from nonprofit hospitals have responded to the reform although they were not subject to any major regulatory change. Third, we have shown that intra-sector competition plays an important role as well: competition between nonprofit hospitals has exacerbated the incentive effects created by the reform, while competition between for-profit hospitals has insulated them from the policy change. Taken together, these results strongly suggest that the utilities supplied to patients are strategic complements.

Understanding strategic interactions in a network has important practical implications, e.g., for regulators conducting policy reforms under budget constraints. In the case of the hospital industry, the shifts in patient flows caused by the reforms have a potentially important impact on public hospital spending. Moreover, these shifts may affect the revenues earned by hospitals and jeopardize their financial viability, which may require transitory measures.

Acemoglu, Ozdaglar, and Tahbaz-Salehi (2015) offer a unified framework for describing the propagation of microeconomic shocks in networks. They conclude on the importance of considering "economies that exhibit richer strategic interactions", pointing out economies with imperfect market competition rather than perfect or monopolistic competition. The present article contributes in this direction by studying industries with spatial nonprice competition. Overall, the proposed network approach proves to be a powerful tool in understanding the equilibrium effects of firm-level shocks in economies with imperfect competition.

[31] By contrast, Duggan (2000) finds that government-owned hospitals are unresponsive to financial incentives. Yet under the reform examined by this author, any increase in the revenues of government-owned hospitals was taken by the local governments that owned them, which is not the case in our setting.

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Appendix

A Proof of comparative statics results

Average relative effect In the configuration of Figure 1(a) where the reaction functions of all firms have the same slope ρ, the propagation matrix defined by (5) is given by

$$G = \begin{bmatrix} 0 & \rho & 0 & \rho \\ \rho & 0 & \rho & 0 \\ 0 & \rho & 0 & \rho \\ \rho & 0 & \rho & 0 \end{bmatrix}. \tag{A.1}$$

When $|\rho| < 1/2$, $I - G$ is a strictly diagonally dominant matrix, and hence is non-singular. Moreover, this matrix is symmetric and circulant.

The inverse matrix $L = (I - G)^{-1}$, therefore, is circulant, too, and we can denote the Leontief coefficients as $l_{jk} = l(k - j)$ where $k - j$ is modulo 4; for instance $l(3) = l(-1)$. Furthermore $l(k - j) = l(j - k)$ because L is symmetric. The Leontief coefficients are given by

$$[l(0),\, l(1),\, l(2),\, l(3)] = \left(\frac{1 - 2\rho^2}{1 - 4\rho^2}, \frac{\rho}{1 - 4\rho^2}, \frac{2\rho^2}{1 - 4\rho^2}, \frac{\rho}{1 - 4\rho^2} \right). \tag{A.2}$$

As announced in the text, we check that $l(0) + l(2) > 2l(1)$ if $\rho > 0$ and $l(0), l(2) > 0 > l(1)$ if $\rho < 0$, which yields (9).

Unused capacities of $\mathcal{N}$-firms We consider the situation represented on Figure 1(b) with three symmetric $\mathcal{S}$-firms and one $\mathcal{N}$-firm. Denoting by ρ_S the common slope of reaction functions of S_1, S_2 and $S_{2'}$ and ρ_N that of N, and numbering the firms according to $\{S_1, S_2, N, S_{2'}\} = \{1, 2, 3, 4\}$, we find that the propagation matrix defined by (5) is given by

$$G = \begin{bmatrix} 0 & \rho_S & 0 & \rho_S \\ \rho_S & 0 & \rho_S & 0 \\ 0 & \rho_N & 0 & \rho_N \\ \rho_S & 0 & \rho_S & 0 \end{bmatrix}. \tag{A.3}$$

Computing $L = (I - G)^{-1}$ and using $\mathrm{d}u_i = [l_{i1} + l_{i2} + l_{i4}]\,\Delta \mathrm{d}r$, we check that

$$\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2} = \frac{\rho_S - 2\rho_S\rho_N}{1 - 2\rho_S^2 - 2\rho_S\rho_N}\Delta \mathrm{d}r.$$

It is easy to check that $\mathrm{d}u_{S_1} - \mathrm{d}u_{S_2}$ decreases (increases) with ρ_N if $\rho_S > 0$ ($\rho_S < 0$). According to Remark B.1, N's unused capacity is associated with a lower slope of its reaction function, ρ_N, hence the results announced in the text.

To study the impact of unused capacities of $\mathcal{N}$-firms on the responses of firms that also belong in $\mathcal{N}$, we consider the configuration shown on Figure 3 with four $\mathcal{N}$-firms and a $\mathcal{S}$-firm located at the center of the circle. The consumers are uniformly distributed over the set consisting of the circle and the four radiuses (SN_i). We normalize the total length of this set (and hence the consumer density) to one. The market share of a firm depends on the utility supplied by that firm and by those supplied by its *three* adjacent neighbors, with $\partial s^j/\partial u_j = 3/(2\alpha)$ and $\partial s^j/\partial u_k$ equal to $-1/(2\alpha)$ if k is an adjacent neighbor of j, and to zero otherwise. The derivative of ρ^j with respect to u_k is the same for all three adjacent neighbors k of firm j and is called hereafter the slope of the reaction function.

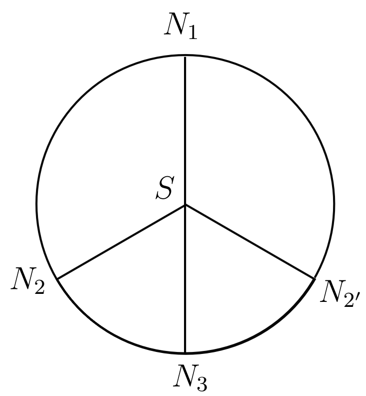

Figure 3: A market configuration with five firms

We assume that N_1, N_2 and $N_{2'}$ have the same reaction function, of common slope ρ_N. These three $\mathcal{N}$-firms are symmetric in every way but their proximity to N_3. We are interested in the effect of N_3's unused capacity on the double difference $\mathrm{d}u_{N_1} - \mathrm{d}u_{N_2}$. We denote by ρ_3 and ρ_S the slope of the reaction function of N_3 and S respectively. Numbering the firms as $\{N_1, N_2, N_3, N_{2'}, S\} = \{1, 2, 3, 4, 5\}$, we find that the matrix defined by (5) is given by

$$G = \begin{bmatrix} 0 & \rho_N & 0 & \rho_N & \rho_N \\ \rho_N & 0 & \rho_N & 0 & \rho_N \\ 0 & \rho_3 & 0 & \rho_3 & \rho_3 \\ \rho_N & 0 & \rho_N & 0 & \rho_N \\ \rho_S & \rho_S & \rho_S & \rho_S & 0 \end{bmatrix}. \tag{A.4}$$

Computing $L = (I - G)^{-1}$ and using $\mathrm{d}u_i = l_{i5}\Delta \mathrm{d}r$, we check that $\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1}$, $\mathrm{d}u_{N_3} - \mathrm{d}u_{N_1}$ and $\mathrm{d}u_{N_3} - \mathrm{d}u_{N_2}$ increase (decrease) with ρ_3 if $\rho_N > 0$ ($\rho_N < 0$). It follows that under strategic complementarity larger amounts of unused capacities at firm N_3 are associated with a weaker response of N_2 relative to that of N_1, as reported in cell B2 of Table 1, and with a weaker response of N_3 relative to that of both N_1 and N_2, as reported in cell A2 of Table 1. The result is reversed under strategic substitutability (cells A4 and B4).

Unused capacities of $\mathcal{S}$-firms We consider the situation represented on Figure 1(c) with three symmetric $\mathcal{N}$-firms and one $\mathcal{S}$-firm, which we label as follows: $\{N_1, N_2, S, N_{2'}\} = \{1, 2, 3, 4\}$. The matrix G is obtained from (A.3) by switching ρ_N and ρ_S. Computing $L = (I - G)^{-1}$ and using $\mathrm{d}u_i = l_{i3}\Delta \mathrm{d}r$, we check that

$$\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1} = \frac{\rho_N - 2\rho_N^2}{1 - 2\rho_N^2 - 2\rho_N\rho_S}\Delta \mathrm{d}r.$$

The amount of unused capacity of firm S has a negative impact on ρ_S and a positive one on the transmission rate Δ, both of which affecting $\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1}$. If $\rho_N < 0$, $\mathrm{d}u_{N_2} - \mathrm{d}u_{N_1}$ unambiguously decreases with the unused capacity of firm S. If $\rho_N > 0$, the same monotonicity properties hold if we assume that in the comparative statics analysis the change in the transmission rate Δ dominates the change in the slope ρ_S.

We now consider the case with four $\mathcal{S}$-firms, Figure 1(d), three of them being symmetric, S_1, S_2 and $S_{2'}$ and the last one being denoted by S_3. We call ρ_S and ρ_3 the slopes of corresponding reaction functions. The matrix G is obtained from (A.3) by replacing ρ_N with ρ_3. Denoting by Δ_S and Δ_3 the transmission rates, we have $\mathrm{d}u_i = [l_{i1} + l_{i2} + l_{i4}]\,\Delta_S \mathrm{d}r + l_{i3}\Delta_3 \mathrm{d}r$. The unused capacity of firm S_3 affects both ρ_3 and Δ_3. The double difference $\mathrm{d}u_{S_2} - \mathrm{d}u_{S_1}$, is linear in $\Delta_3 \mathrm{d}r$, with the contribution of Δ_3 being

$$\frac{\rho_S(1-2\rho_S)}{1-2\rho_S^2-2\rho_S\rho_3}\Delta_3 \mathrm{d}r.$$

This double difference therefore increases (decreases) with Δ_3 if $\rho_S > 0$ ($\rho_S < 0$), hence the results reported in cells C1 and C3 of Table 1. It is easy to check that the differences $\mathrm{d}u_{S_3} - \mathrm{d}u_{S_1}$ and $\mathrm{d}u_{S_3} - \mathrm{d}u_{S_2}$ are linearly increasing in Δ_3, with slope $(1-2\rho_S)(1+\rho_S)/(1-2\rho_S^2-2\rho_S\rho_3) > 0$, hence the results reported in cells A1 and A3 of the table.

B Nonprice competition with linear incentives

The purpose of this section is to provide microeconomic foundations for the role of unused capacities as described in Section 3.3. To this aim, we rely on a non-price competition model where marginal costs increase with the utility supplied to consumers and can be reduced through managerial efforts. As explained below, these forces play in opposite directions, making the nature of strategic interactions a priori ambiguous. Having in mind our application to the hospital industry, we allow for the possibility of a third force, namely intrinsic motivation or altruism.[32]

Denoting by u the utility supplied to patients, by e the level of cost-containment effort,[33] and by λ_h the marginal utility of revenue, we specify the objective function of hospital h as

$$V^h(e,u) = \lambda_h \pi^h - \frac{b_h}{2}u^2 - \frac{w_h}{2}e^2 + (v_h + a_h u)\, s^h. \tag{B.1}$$

The profit function π^h is the difference between revenues and total pecuniary costs. Revenues consist of a payment received from the government, namely a lump-sum transfer $\bar{R}_h$ and a payment per discharge $r_h \geq 0$ for hospital h. Costs consist of a fixed part F_h and a variable part $(c_{0h} - e + c_h u)\, s$:

$$C^h(s,u,e) = F_h + (c_{0h} - e + c_h u)\, s. \tag{B.2}$$

The marginal pecuniary cost per admission, $c_{0h} - e + c_h u$, is constant and linearly

[32] The model is much inspired from earlier studies, e.g. Pope (1989), Ellis (1998), Brekke, Siciliani, and Straume (2011), and Brekke, Siciliani, and Straume (2012).

[33] Below we express e as a function of u, which brings us back to the framework of Section 3.1 where the utility supplied to patients is the sole strategic variable.

increasing in the utility offered to patients. The second and third terms in the objective function V^h represent the non-pecuniary costs of managerial efforts to raise the utility supplied to patients and to lower the hospital marginal cost.The last two terms in (B.1) represent non-financial motives to attract patients. Hospital managers may value the number of patient admissions, perhaps because hospital activity has positive spillovers on their future careers. This motive is reflected in third term $v_h s$ of (B.1). The term $a_h us$ expresses the altruistic motive, whereby manager and staff enjoy providing high utility to patients.[34]

The hospitals simultaneously choose cost-containment effort and the level of gross utility offered to patients to maximize their objective functions

$$V^h = [\lambda_h r_h - \lambda_h c_{0h} + \lambda_h e + v_h + (a_h - \lambda_h c_h)u]\, s^h - \frac{b_h}{2}u^2 - \frac{w_h}{2}e^2 + \lambda_h(\bar{R}_h - F_h).$$

By the envelope theorem, the perceived marginal utility to increase the utility offered to patients is given by

$$\begin{aligned} \mu^h(u_h, u_{-h}; r_h) &= \left[v_h - \lambda_h c_{0h} + \lambda_h r_h + \lambda_h e^h + (a_h - \lambda_h c_h)u_h\right] \frac{\partial s^h}{\partial u_h} \\ &\quad + (a_h - \lambda_h c_h)s^h - b_h u_h, \end{aligned} \tag{B.3}$$

where $e^h(u_h, u_{-h}) = \lambda_h s^h / w_h$ is the level of cost-containment effort chosen by hospital h. A positive shock on the rate r_h has the same effect on the firm's incentives as a negative shock of same absolute magnitude on the marginal cost c_{0h}.

When λ_h equals zero, financial profits do not enter the hospital objective; cost-containment efforts are zero, and the hospital chooses u_h that maximizes the function $(v_h + a_h u_h)\, s^h(u_h, u_{-h}) - b_h u_h^2/2$ which we assume to be quasi-concave in u_h. For positive values of λ_h, the hospital manager puts a positive weight on financial performances. The limiting case of infinitely high λ_h corresponds to pure profit-maximization and is ill-adapted to describe the objective of nonprofit hospitals. In fact, those hospitals were subject to global budgeting ($r_h = 0$) prior to the reform, and hence would have had no incentives at all to attract patients in the pre-reform regime if they were pure profit-maximizers.

As Dafny (2009) or Gal-Or (1999), we assume that the patients are uniformly distributed on the Salop circle and normalize the length of that circle (and hence

[34]The same gross utility u is offered to all treated patients. To simplify the exposition, we assume here as in Ellis (1998) that patient travel costs do not enter providers' objective functions.

the patient density) to one. The demand addressed to hospital h is given by

$$s^h(u_h, u_l, u_r) = \frac{d_{hl} + d_{hr}}{2} + \frac{u_h}{\alpha} - \frac{u_l + u_r}{2\alpha},$$

where u_l and u_r denote the utilities offered by the left and right neighbors, and d_{hl} and d_{hr} are the distances between h and those neighbors. We therefore have: $\partial s^h/\partial u_h = 1/\alpha$ and $\partial s^h/\partial u_{-h} = -1/(2\alpha)$.

Transmission Under the linear specification described above, the transmission rate, defined in (4), is given by

$$\Delta_h = \frac{\lambda_h}{2(\lambda_h c_h - a_h) + \alpha b_h - \lambda_h^2/(\alpha w_h)} \tag{B.4}$$

for each $\mathcal{S}$-firm h. The denominator of the above ratio is of the sign of $-\partial\mu^h/\partial u_h$, hence positive by the second-order conditions. The transmission rates are therefore positive: higher reimbursement rates encourage hospitals to increase the utility they supply to patients. This property is related to the absence of revenue effects in the linear model, which we discuss in Appendix C.

Reaction functions Differentiating (B.3) yields

$$\frac{\partial\mu^h}{\partial u_h} = \frac{2}{\alpha}(a_h - \lambda_h c_h) - b_h + \frac{\lambda_h}{\alpha}\frac{\partial e^h}{\partial u_h} \quad \text{and} \quad \frac{\partial\mu^h}{\partial u_{-h}} = -\frac{1}{2\alpha}(a_h - \lambda_h c_h) + \frac{\lambda_h}{\alpha}\frac{\partial e^h}{\partial u_{-h}}.$$

Differentiating the cost-containment effort function $e^h(u_h, u_{-h}) = \lambda_h s^h/w_h$, we find $\partial e^h/\partial u_h = \lambda_h/(\alpha w_h)$ and $\partial e^h/\partial u_{-h} = -\lambda_h/(2\alpha w_h)$. The reaction function of hospital h, $u_h = \rho^h(u_{-h}; r_h, \bar{R}_h)$, depends only on the utilities offered by its left and right neighbors. It is actually linear in those two utilities, with slope

$$\rho_h = -\frac{\partial\mu^h/\partial u_{-h}}{\partial\mu^h/\partial u_h} = \frac{1}{2} \cdot \frac{\lambda_h c_h - a_h - \lambda_h^2/(\alpha w_h)}{2(\lambda_h c_h - a_h) + \alpha b_h - \lambda_h^2/(\alpha w_h)}. \tag{B.5}$$

The matrix coefficient g_{hk} defined in (5) is equal to ρ_h if h and k are adjacent neighbors and to zero otherwise. We have already seen that the denominator is positive. It follows that the reaction function is upward-sloping if and only if $(\lambda_h c_h - a_h)/\alpha - \lambda_h^2/(w_h\alpha^2) > 0$. As the derivative $\partial\mu^h/\partial u_h = \partial^2 V^h/\partial u_h^2$ is negative by the second-order condition of the hospital problem, the sign of ρ_h is given by the sign of $(\lambda_h c_h - a_h)/\alpha - \lambda_h^2/(w_h\alpha^2)$.

As explained in Section 4.2, the gross utilities offered to patients can be either strategic complements ($\rho_h > 0$) or strategic substitutes ($\rho_h < 0$). On the one hand, the costliness of quality pushes towards complementarity as in standard price competition. Because its total costs include the product $c_h u_h s^h$, see (B.2), hospital h finds it less costly to increase quality when u_{-h} increases and s^h decreases. Hospital h therefore has extra incentives to raise u_h, hence strategic complementarity. On the other hand, altruism and cost-containment effort push towards strategic substitutability. The intuitions for the latter two effects are as follows. As u_{-h} rises, fewer patients are treated by hospital h, hence a weaker altruism motive for that hospital to increase u_h; this effect materializes in the term $a_h s^h$ in (B.3). At the same time, the endogenous cost-containment effort, $e^h = \lambda_h s^h / w_h$, falls because the reduced marginal cost applies to fewer patient admissions, which, again, translates into weaker incentives μ^h as u_{-h} rises.[35]

Lemma B.1 (Effect of unused capacities)**.** *Assume that the cost parameters c_h and w_h* decrease *with the margin of unused capacity. Larger margins of unused capacity are associated with stronger transmission rates (for h in $\mathcal{S}$) and lower slopes of the reaction functions.*

Proof. Considering first transmission rates, we see from (B.4) that the magnitude of Δ_h decreases with c_h and w_h. The $\mathcal{S}$-firms respond more vigorously to stronger incentives when these two costs parameters are lower. It then follows from the assumption of the Lemma that the transmission rate Δ_h for $h \in \mathcal{S}$ *increases* with the firm's unused capacity. In other words, abstracting away from equilibrium effects, $\mathcal{S}$-firms react more vigorously when they have larger amounts of unused capacity.

Turning to reaction functions, we now check that ρ_h increases with c_h or equivalently in $\lambda_h c_h$ at given λ_h. We first recall that the denominator of (B.5) is positive and we observe that the ratio $(x + x_1)/(x + x_0)$ increases with x at the right of its vertical asymptote, i.e., in the region $(-x_0, \infty)$, if and only if $x_0 > x_1$. This yields the desired results with $x_0 = -a_h + \alpha b_h/2 - \lambda_h^2/(2\alpha w_h)$ and $x_1 = -a_h - \lambda_h^2/(\alpha w_h)$.

We now adapt the argument to check that ρ_h increases with w_h or equivalently with $z_h = -\lambda_h^2/(\alpha w_h)$ at given λ_h and α. We use $x_0 = 2(\lambda_h c_h - a_h) + \alpha b_h$ and $x_1 = \lambda_h c_h - a_h$. We have $x_0 > x_1$ in particular when the pecuniary cost dominates the altruism force, $\lambda_h c_h - a_h \geq 0$. In the opposite case, $\lambda_h c_h - a_h < 0$, we have

[35] Formally, the fall in μ_h materializes in the term $\lambda_h e^h/\alpha = \lambda_h^2 s^h/(\alpha w_h)$ of equation (B.3) that decreases with u_{-h}.

$\rho_h < 0$ since the numerator in (B.5) is then negative. It follows that ρ_h is below its horizontal asymptote, $\rho_h < 1/2$, and since we are at the right of its vertical asymptote, ρ_h must increase in z_h, and hence in w_h. □

C Marginal utility of revenue

We now examine how hospitals with different (exogenous) marginal utilities of revenue respond to stronger reimbursement incentives. Then, and independently, we consider the possibility of revenue effects, i.e., that marginal utilities of revenue are affected by the policy shock.

Heterogenous marginal utility of revenue To examine the impact of a hospital's marginal utility of revenue on its own response, we use the linear specification of Appendix B. The second-order condition of the hospital problem is satisfied if and only if the denominator of (B.4) is positive. As already mentioned, when $\lambda_h = 0$, the program of hospital h boils down to $(v_h + a_h u_h)\, s^h(u_h, u_{-h}) - b_h u_h^2/2$ which is concave if and only if $\alpha b_h - 2a_h > 0$. Under this assumption, we can let the marginal utility of revenue λ_h vary between zero and a maximum threshold, and we observe that the transmission rate Δ_h increases with λ_h over this interval.[36] Following the same analysis as above (effect of own unused capacities, cells A1 and A3 of Table 1), we find that a higher marginal utility of revenue is associated with stronger transmission for $\mathcal{S}$-firms, which tends to increase their response $\mathrm{d}u_h$.

Revenue effects and budget-neutral reforms Under the linear specification of Appendix B, the hospital marginal utility of revenue is exogenous, i.e., there is no revenue effect. The variations in hospital revenues induced by the reform have no impact on hospital behavior. For the same reason, the fixed parts of the reimbursement schedule, $\bar{R}_h$, play no role in the analysis.

In general, however, the presence of an revenue effect could reverse the reimbursement incentives, making the sign of Δ_h ambiguous. Indeed a rise in r_h may increase the hospital revenue, thus lowering its marginal utility of revenue and hence its incentives to attract patients.

The indeterminacy is resolved if we restrict our attention to budget-neutral reforms. Starting from a situation where the lump-sum transfers $\bar{R}_h$ are all positive,

[36] The effect of λ_h on the slope of its reaction function, ρ_h, is not obvious as λ_h interacts with c_h and $1/w_h$ in (B.5).

we now show that, for any given variations of the reimbursement rates, $\mathrm{d}r_h \geq 0$, there exist variations of the fixed transfers $\mathrm{d}\bar{R}_h$ such that the revenue of each hospital is the same before and after the reform –and consequently the reform does not affect the government expenditures. Indeed, differentiating the first-order condition $\mu^h(u_h, u_{-h}; r_h, \bar{R}_h) = 0$ at constant revenue yields variation of the utilities u_h and of the market shares s^h. To keep hospital total revenues $R_h + r_h s^h$ fixed, the government must change the lump-sum transfers $\bar{R}_h$ by $\mathrm{d}\bar{R}_h = -s^h \mathrm{d}r_h - r_h \mathrm{d}s^h$.

In the case of the French reform studied in this article, the regulator reduced the lump-sum transfers to limit as much as possible the induced variations in hospital revenues. When revenue effects are neutralized, the transmission rate of the reform is positive, $\Delta_h \geq 0$: the hospitals subject to the reform are encouraged to increase the utility offered to consumers, given the behavior of their competitors.