Absorptive Capacity, Knowledge Spillovers and Incentive Contracts[1]

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Abstract

We attempt to identify and measure knowledge spillovers in the French urban transport sector, which is strongly regulated and where a few large industrial groups are in charge of operating several urban networks. We build and estimate a structural cost model where the service is regulated by a local government and is provided by a single operator. Knowledge spillovers are directly linked to the know-how of a specific group, but they also depend on the incentive power of the regulatory contract which shapes the effort of the local managers. Exerting an effort in a specific network allows a cost reduction in this network, but it also benefits other networks that are members of the same group. We find that diversity of knowledge across operators of the same group improves absorptive capacity and increases the flow of spillovers. Simulation exercises provide evidence of significant reductions in total operating costs following the enlargement of industrial groups.

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1 Introduction

Knowledge spillovers are usually seen as a process in which firms obtain new knowledge from external sources. They are interpreted as externalities in a competition game where the agents are unable to fully appropriate all benefits from their own R&D activities. Knowledge spillovers are key ingredients of firms' productivity and economic growth (Jaffe, 1986, Romer, 1990, Grossman and Helpman, 1991). The economic literature has discussed to a large extent issues related to R&D and the production of knowledge spillovers. Important challenges have been the measurement of spillovers between firms, the identification of the factors that influence their generation, whether firms are able to fully take advantage of incoming spillovers and appropriate their proprietary knowledge and whether knowledge externalities are geographically localized (see for instance Bernstein and Nadiri, 1989, Jaffe, Trajtenberg, and Henderson, 1993, Audretsch and Feldman, 1996, Cassiman and Veugelers, 2002, and Bloom, Schankerman, and Van Reenen, 2013).

In this paper, we propose to focus on the issue of the identification of spillovers in the particular case of the regulation of firms with incentive contracts (Laffont and Martimort, 2002). There are two important features in our model: First, the incentive power of each regulatory contract directly shapes the operator's R&D intensity which is re-interpreted as the cost-reducing effort activity in our setting. Second, spillovers here are measured within the industrial groups that provide public services in several urban areas simultaneously. Thus, spillovers are directly linked to the know-how of a specific group, but they also depend on the decisions taken by a local manager.

We apply our framework to the French urban transport industry, which is particularly well fitted for our purpose. In each urban network of significant size, a local authority regulates and monitors public transport services while a single firm (the operator) is in charge of the operation within a specific regulatory framework. The latter takes the form of a written contract that defines the payment and cost-reimbursement rules between the parties. Fixed-price contracts are implemented in a very large majority of urban areas. Under a fixed-price regime, the operator receives subsidies to cover ex-ante (expected) operating deficits, and is thus provided with powerful incentives to reduce operating costs.[4]

[4]Cost-plus regulation got introduced in the 1970s but became less popular after the central govern-

A distinguishing feature of this industry is that about eighty percent of the local operators are owned by three large industrial groups. The transport services provided in different urban networks by operators belonging to the same industrial group are therefore, in essence, provided by the same productive unit. This peculiarity suggests that these operators may benefit from the exchange of information and feedback on experience across many networks operated in different localities with different characteristics. In other words, the economic activity involved in one specific network may affect the economic activity in other networks operated by the same company. In the specific context of the urban transport industry, we expect these spillovers or externalities to take place when a cost-reducing activity developed by one of the operators reaches other productive units of the group. Hence, all networks operated by the same group benefit from the cost-reducing efforts provided by all the members of the group. To reflect the fact that these spillovers could be related to a large array of know-how generated by the operator, ranging from technological to organizational, we will refer to them as knowledge spillovers throughout the text.

In order to be able to exploit incoming spillovers, operators need to work on their absorptive capacity. The latter depends on the ability of the operator to identify the value of new information and assimilate it, which potentially entails basic skills, similar languages, or scientific or technological capabilities. We therefore build and estimate a structural cost regulation model that accounts for the fact that R&D expenditures (the effort of the operator) and absorptive capacity are directly related and allow the production of knowledge spillovers. In each given city, the operator is one of the three large industrial groups present in France or it can be an independent local entity. In both cases, the operations are run by a local manager who decides upon the effort level to be exerted to reduce the operating costs of the local transportation activity. The operator maximizes its own profit and determines the optimal effort level. The latter depends on the local incentives, but it is also affected by all the other effort activities exerted by the other operators of the same group. The econometric task consists then in recovering the parameters of a static model of cost regulation, and testing for the

ment decided in 1982 that the financial responsibility of the transport operations would rest on the shoulders of local municipalities. We discard cost-plus regimes in our analysis as we are interested in the synergies across operators regulated by fixed-price contracts. As suggested in Gagnepain, Ivaldi, and Martimort (2013), fixed-price schemes are usually chosen by more efficient operators in a sense to be defined in what follows. We are not concerned by a potential selection bias as we mostly care about relative changes in cost distortions within a group of operators regulated under fixed-price regimes.

relevance of knowledge spillovers. Our results suggest that the flow of knowledge spillovers across the members of the same group are significant and increase with the size of the group, and they allow transport operators to obtain significant cost reductions. Moreover, operators' activities that present larger differences in characteristics relative to their group benefit to a larger extent from the efforts provided by other operators of their group. Thus, while a minimum degree of overlap of knowledge across operators is necessary for internal communication, there are also benefits to diversity of knowledge and organizational structures across networks.

Our work shares features with different strands of the empirical literature. On the one hand, our paper contributes to the recent empirical literature on incentive regulatory policies. Gagnepain and Ivaldi (2002 and 2017), and Gagnepain, Ivaldi and Martimort (2013) focus on the same type of data and show that fixed-price contracts lead to a significant decrease of the operating costs of the local operators in France. Our model builds on a similar framework and assumes moreover that the technology of each local operator is not independent of the decisions of the other managers that belong to the same industrial group. Thus, following Holmstrom (1982), we argue here that group incentives matter, although there is no monitoring from the headquarter in our framework. From that perspective, our paper is one of the first to take into account knowledge spillovers in a regulation context.

On the other hand, our paper also relates to the empirical literature on R&D knowledge spillovers with the difference that it focuses on spillovers within operators rather than across operators.[5] Most related to our paper is the work of Klette (1996), which uses data on Norwegian manufacturing firms and analyzes the interaction between firm performance and R&D expenditures. The author evaluates R&D at the line-of-business level within each firm and also identifies firms that belong to the same interlocking group of firms, i.e., the set that includes a parent company and all subsidiaries in which the parent company owns a majority share of equity. The paper sheds light on significant spillover effects across different lines of business (e.g. chemicals or metal products) within a firm but also reveals significant spillovers for activities within a line of business that are carried out by different firms within the same group. Szulanski (1996) analyzes firms' ability to diffuse best practices internally. The paper suggests

[5] A more general discussion on franchise contracts, reputation, and umbrella branding entails for instance Klein and Saft (1985), Andersson (2002), and Hakenes and Peitz (2008).

that the main barriers to internal knowledge transfer are knowledge-related factors such as the recipient's lack of absorptive capacity. In our framework, we identify the absorptive capacity for each industrial group in our industry and find evidence of diffusion of knowledge spillovers across transport operators linked to the same group. In particular, we are able to construct indices that relate to the structural differences between a given network and the remaining networks from the same group. Another related example is Darr, Argote, and Epple (1995), which analyzes knowledge transfers acquired through learning-by-doing in service organizations. The authors focus on pizza stores owned by different franchisees and find evidence of knowledge transfer across stores owned by the same franchisee but not across stores owned by different franchisees. A related issue highlighted by the literature is the importance of free-riding among the different franchisees of a given chain (see for example Brickley, 1999, and Lafontaine and Slade, 1997, 2007). A franchisee has incentives to free-ride on the tradename of the franchisor given that her effort is private while the benefits will accrue to all the members of the chain. This closely relates to our model where each local operator privately pays the cost of its effort which will be beneficial to all members of the same industrial group.

The organization of the paper is as follows: Section 2 describes the regulation of urban transportation in France in more detail and discusses the assumptions that are maintained throughout the paper. Section 3 presents our model of cost regulation which encompasses the main features of urban transportation and the environment in which operators make their decisions. Section 4 then develops a formal specification of the cost function to be estimated. Section 5 is devoted to the construction of the variables and the presentation of our results. Section 6 evaluates the cost gains of adding operators to a group. Section 7 provides a summary and some concluding remarks.

2 The French Urban Transportation Industry

As in most countries around the world, urban transportation in France is a regulated activity. Local transportation networks cover each urban area of significant size, and for each network, a local authority (a municipality, a group of municipalities or a district) is in charge to regulate an operator which has been selected to provide the transportation service. Regulatory rules prevent the presence of several suppliers of transportation services in the same urban network, and each network is therefore operated by a single operator. Each local authority organizes its own transportation system by setting route and fare structures, capacity, quality of service, conditions for subsidizing the service, levels of investment and ownership nature. The local authority may decide to operate the network directly or to acquire the services of a transport service provider. In the latter case, a formal contract defines the regulatory rules that the operator must follow as well as the cost-reimbursement scheme between the authority (the principal) and the operator (the agent). In most urban areas, operating costs are at least twice as high as commercial revenues (Commissariat Général au développement Durable, 2018). Budgets are therefore rarely balanced without subsidies.[6]

During our period of observation, about eighty percent of local operators are private and are owned by three large companies, two of them being private while the third one is semi-public. In 2002, these companies, with their respective ownership structures and market shares (in terms of number of networks operated) were Keolis (private, 30%), Transdev (semi-public, 19%), and Connex (private, 25%). In addition there is a small private association, Agir, and a few public operators controlled by local governments.[7]

Fixed-price contracts are implemented in a large majority of urban areas. In this case, the operators receive subsidies to finance the expected operating deficits; thus, fixed-price regimes should be interpreted as high-powered incentive schemes. The automatic renewal of the contract between the local authority and the operator in place

[6]One reason is that operators face universal service obligations and must operate in low demand areas. Low prices are maintained to ensure affordable access to all consumers of public transportation. Moreover, special fares are given to targeted groups like seniors and students. Subsidies come from the State's budget, the local authority's budget, and a special tax paid by local firms (employing more than nine full-time workers). In addition to the price distortions causing deficits, informational asymmetries that affect the cost side and lead to inefficiencies make it more difficult to resume these deficits.

[7]Industrial groups involved in the provision of urban transport services have a long history of mergers in France. Keolis was born out of the merger of several companies created in the beginning of the 20th century. The *Société des transports automobiles*, created in 1908, its subsidiary (the *Société générale des transports départementaux*) and the company *Lesexel*, founded in 1911 to help on the development of tramways, merged to form the VIA-GTI company, mainly focused on urban transport. In the meantime, another company, *Cariane,* was specialized in the French interurban transport. Ultimately, VIA-GTI and *Cariane* merged in 2001 to give birth to Keolis. The industrial group Connex was born out of the merger of the *Compagnie Générale Française des Transports et Entreprises* (CGFTE) and the *Compagnie Générale d'Entreprises Automobiles* (CGEA) in the late 1980's. The company was ultimately renamed *Veolia Transport* in 2005. Finally, the Transdev group was created in 1955. On March 3rd 2011, it merged with *Veolia Transport* to give birth to *Veolia Transdev.*

was effectively ended, by law, in 1993. Since then, local authorities are required to use beauty contests to allocate the construction and management of infrastructures of urban transportation. In practice, however, very few networks have experienced change of operators from one regulatory period to another.[8] As a matter of fact, the three main groups succeeded in committing to distinct geographical areas (See Figure 1) and reducing the degree of competition in the awarding of transport operations in urban areas where the regulatory contract came to an end. Competitive tendering is therefore not a relevant issue in this sector, and ex-ante competition is not so fierce. Finally, these groups also operate other municipal services such as water distribution or garbage collection, which makes it even harder for public authorities to credibly punish operators following bad performance in the provision of transport services. It follows that group structures are rather stable both across networks and over time in our sample.[9]

Our objective is to take these features of the urban transport industry into account and to perform an analysis of the observed regulatory schemes within a principal-agent setting. This requires a database that provides information on both the performance and the organization of the French urban transport industry. Such a database was created in the early 1980s from an annual survey conducted by the *Centre d'Etude et de Recherche du Transport Urbain* (CERTU, Lyon) with the support of the *Groupement des Autorités Responsables du Transport* (GART, Paris), a nationwide trade organization that gathers most of the local authorities in charge of an urban transport network. In France, this rich source is a unique tool for comparing observed regulatory schemes both across year and over time. In our econometric analysis, we consider the regulatory scheme adopted in each urban area during a year as a realization of the same regulatory contract. Overall, the panel data set covers 67 different urban transport

[8]Over the period covered by our analysis, only 5 networks have decided to get rid of their operators to select another company. Out of these, two changed from being operated by an operator belonging to a group to being operated by an independent operator, while only one network changed from being operated by an independent operator to being operated by an operator belonging to a group. Finally, only 2 networks saw their operator change from an operator belonging to a given group to an operator belonging to another group.

[9]The multi-market contact structure of the industry is another potential ingredient that eases the operators' ability to soften competition (Bernheim and Whinston, 1990). In 2005, the French Competition Authority fined Kéolis, Connex, and Transdev a total amount of 12 million euros for agreeing, between 1996 and 1998, on sharing the local markets for urban public passenger transport in France (Decision 05-D-38 of July 5th, 2005). The lack of competition could exacerbate the cost distortions in our empirical analysis but should not be a concern for the evaluation of the cost synergies within a group.

networks over the period 1987-2001.[10]

As a result, the organization and structure of the urban transportation industry in France as described above motivates the following assumptions.

Assumption 1 - *Asymmetric information*: The expertise of the regulator is limited.

In France, local authorities have been historically blamed for their laxness in assessing operating costs, mainly because of their lack of knowledge and experience of transportation economics and technologies, and/or because of their limited capacity of monitoring and auditing complex operating activities. These considerations prevent them to adequately assess the effort of operators in providing appropriate and competent solutions to cost and operators' inefficiencies.

We thus assume that the network operator has private information about its innate technology (which will be interpreted as the inefficiency parameter in what follows) and that its cost-reducing effort is non-observable. Because French transport authorities are politicians from the local municipal councils instead of transport professionals, their limited auditing capacities are recognized among practitioners. A powerful and well-performed audit system needs effort, time and money. French experts on urban transportation blame local authorities for being too lax in assessing operating costs.[11] The number of buses required for a specific network, the costs incurred on each route, the fuel consumption of buses (which is highly dependent on drivers' skills), the drivers' behavior toward customers, the effect of traffic congestion on costs, are all aspects for which operators have much more data and a better understanding than public authorities.[12]

[10]The sample does not include the largest networks of France, i.e., Paris and Marseille, since there is no delegation of service in these cities (the regulator and the operator are the same entity).

[11]An official statement on the weak capabilities of expertise of the local governments and the lack of ex ante competition in the industry is proposed by the French court of auditors (Cour des Comptes) in its 2005 report. See https://www.ccomptes.fr/fr/publications/les-transports-publics-urbains.

[12]Gagnepain and Ivaldi (2002) confirmed through a test that adverse selection and moral hazard are two important features of the industry. They showed that a regulatory framework which encompasses these two ingredients performs well to explain the data.

Assumption 2 - *Spillovers*: Technological innovation may spill-over across operators of the same industrial group.

In France, the 1982 Transportation Law was enacted to facilitate decentralized decision-making on urban transportation and to provide guidelines for regulation. Since then, each local authority organizes its own transportation system and is responsible for cost overruns in case of bad performance of the operator. As a result, fixed-price regimes become more popular after 1982. Providing effort is directly related to the innovation process and the R&D activity of the operator.[13] It is first related to the action of managers who spend time and energy in improving the location of inputs within the network (the main concern is the management of bus drivers), finding cheaper suppliers, bargaining better procurement contracts, subcontracting non-essential activities, monitoring employees, or solving potential labor conflicts. It also entails the development of a computerized information system which allows the operator to observe in real time the position of all vehicles in the network, changes in environmental friendly energy standards and propulsion systems, or trip information to travelers. Finally, the operator might negotiate with the regulator the introduction of bus priority or guided busway on specific network segments in order to improve commercial speed, or the use of smaller vehicles or low floorbus, the design of timetable and frequency, or pricing and marketing strategies. Networks in different urban areas may share heterogeneous features and topology, hence the experience and innovative activity of one operator might benefit other operators that belong to the same industrial group and operate transport services elsewhere.

The larger industrial groups, Keolis, Connex and Transdev, have in each network they operate a local manager who takes care of running the network and has decision rights on the effort to be exerted in order to decrease operating costs. Given this decision-making configuration, we expect actions related to cost-reducing activities taken in a specific network to generate a positive externality on the operating costs of the remaining operators of the group. The main idea is that knowledge generated in a given location can be processed by the group's headquarters and later be transmit-

[13]Innovation in public transportation is usually triggered by changes in the regulation of the service. A first well known example is the British deregulation case, which came from the Transport Act of 1985 and set the local bus service in Great Britain. A second one is the introduction of the new Passenger Transport Act 2000 in the Dutch public transport industry which decentralized the powers to provincial and regional authorities (Ongkittikul and Geerlings, 2006).

ted and used in another network operated by the group. For instance, the results of process R&D obtained in one location can spill-over to another operator through the group's headquarters. The latter operator would therefore benefit from (part of) this R&D without investing as much effort as it would have to if it were independent. Similarly, the effort incurred to find a cheaper supplier in one network may reduce the need to look for a cheaper supplier in another city. The bargaining of procurement contracts may also be easier if the operator belongs to a group with relevant experience in other networks. Likewise, methods to efficiently monitor employees could also be learned in a given place and transmitted to another. In that sense, an operator belonging to a group will benefit from positive externalities coming from the effort exerted by all the remaining operators of the group. Whether the knowledge generated in a given location is transferable or applicable to another network of the group might depend on the absorptive capacity of the operators and/or network characteristics in a sense to be defined in what follows.

We now build a structural cost function that accounts for the incentive power of the contract faced by the operator as well as for the structure of the group it belongs to, if any. This allows us to test for the relevance of knowledge spillovers among operators in the French urban transport industry.[14]

3 The Economic Model

We now present a model of regulation of the urban transport industry that generalizes Gagnepain and Ivaldi (2002) to the case of groups of operators that rely on each other's effort. Starting from the technology associated with the transportation activity, we first define the primal operating cost function, which is conditional on the cost-reducing activity of the operator. We describe how the fixed-price regime and the structure

[14]Three additional remarks should be made. First, private information on demand is not a relevant issue in our industry. Local governments are well informed about the transportation needs of citizens. The number of trips performed over a certain period is easily observed, and the regulator has a very precise idea of how the socio-demographic characteristics of an urban area fluctuate over time. Given the level of demand, the regulator sets the service capacity provided by the operator. Second, we do not address the issue of determining what should be the optimal rate-of-return on capital. The rolling stock is owned by the local government for a vast majority of networks. In this case, the regulator is responsible for renewing the vehicles, as well as guaranteeing a certain level of capital quality. Finally, we rule out the possibility of risk sharing in the contractual relationships between the operators and the regulators since the provision of transport services does not entail unpredictable cost fluctuations for the operators.

of the transport groups affect the operators' choice of cost-reducing effort. Once the optimal level of effort is determined, we plug it back into the conditional cost function to obtain the final cost function that captures all the relevant incentives affecting the activity of the operator.

Technology and primal cost function

To provide the required level of services Q, the transit operator needs to combine variable and fixed inputs. Let $w = (w_L, w_M)$ be the price of variable inputs, namely labor (L) and materials (M). Let K and I be, respectively, the stock of capital and the infrastructure used by the operator, which are both fixed in the short run. The production process is then represented with the production function $Q = f(K, I, L, M|\lambda)$, where λ is a vector of parameters characterizing the technology. We denote by C the observed operating cost of each operator. As the stock of capital K and the size of the infrastructure I are determined by the regulator, our cost function is determined in the short run, and is conditional on the stock of capital and on the size of the infrastructure.[15] Each operator i chooses the cost-minimizing input allocation subject to technological constraints, which leads to a cost function of the following form:

$$C_i^0 = C_i^0(w_i, Q_i, I_i, K_i|\beta), \tag{1}$$

where β is a vector of parameters characterizing the cost function. In reality, the actual operating cost may differ from the minimum operating cost defined by (1). Inefficiencies may prevent operators from reaching the required level of service Q at the minimum cost, which will result in upward distorted costs. To counterbalance these inefficiencies, however, operators can undertake cost-reducing activities to which we will refer as R&D effort.

A given operator i operating a specific network can be either independent or belong to one of each of the industrial groups $g = \{Keolis, Transdev, Connex\}$, which operate a set of n_g urban networks. While production inputs are exclusively network specific, we assume the inefficiencies to affect all the n_g networks of a given group g. Likewise,

[15]In practice, the operator plays a role in the choice of investment, which, potentially, introduces another dimension that can be affected by information asymmetries. Our understanding of the industry is that this question is of second-order since, for instance, the production of new buses, which could have a drastic impact on the efficiency of the transport network, takes time and refers to periods longer than regulatory periods.

we expect the R&D efforts exerted in a given network to affect the operating cost of other operators belonging to the same industrial group. These spillovers are, however, not present for an independent network. We return to these points more in details below.

Denote by θ_g the group specific inefficiency parameter, and let θ_i be the inefficiency level of an independent operator i. We denote the R&D effort level of operator i belonging to group g as e_{ig}, and let e_{-ig} denote the effort of the remaining operators of the same group. Let e_i be the R&D effort level of an independent operator i. Note that both the inefficiency and the effort levels are unobservable to the regulator and to the econometrician. Each operator therefore faces a cost function that defines the frontier of minimum operating costs conditional on the levels of capital, infrastructure, inefficiency, effort and group structure. Specifically, operator i faces a cost function of the form:

$$C_i(C_i^0, \theta, e|\beta) = \begin{cases} C_i^0 \times \phi\left(\theta_i, e_i\right), & \text{if } i \text{ is independent} \\ C_i^0 \times \phi\left(\theta_g, e_{ig}, \kappa_{ig} e_{-ig}\right), & \text{if } i \in g. \end{cases} \tag{2}$$

Here, $\phi\left(\theta, e\right)$ is a continuous function that is increasing in θ and decreasing in e. A direct measure of the knowledge spillovers obtained by operator i is given by $\kappa_{ig} e_{-ig}$ while κ_{ig} should be seen as the absorptive capacity of the operator. Following Cohen and Levinthal (1989 and 1990) and Kamien and Zang (2000), the absorptive capacity denotes the ability of the operator to exploit incoming spillovers. It depends on the ability of the operator to identify the value of new information and assimilate it, which potentially entails basic skills, similar languages, or scientific or technological capabilities. Note that these authors also claim that R&D expenditures and absorptive capacity are directly related as R&D develops the operator's ability to identify, assimilate, and exploit incoming knowledge. In our model, operators take into account the enhancement of absorptive capacity in determining their R&D expenditure level as e_{ig} depends directly on κ_{ig}. Moreover, we expect κ_{ig} to depend both on network and group characteristics, as the networks within the same group should benefit asymmetrically from knowledge spillovers. We discuss more thoroughly the identification of κ_{ig} in what follows.

Note finally that, while the inefficiency parameter θ is exogenous, the cost reducing effort is a choice variable which will depend on both the contract that the operator faces and on the structure of the group it belongs to, if any. We next turn to the operator's effort decision and to the construction of the structural cost function.

Incentives, knowledge spillovers and the optimal level of effort

Under a fixed-price contract, the operator obtains an ex-ante subsidy t equal to the expected balanced budget, i.e., the difference between expected costs and expected revenues. This contract is a very high-powered incentive scheme as the operator is residual claimant for effort.

Assumption 3 - *Equilibrium*. We model the effort game for each operator inside a group as a static game of complete information where each operator takes the others' effort as given.

Each urban network run by a group has a local manager in charge of the transport operations. Each manager is concerned about local profits, but the local cost-reducing R&D effort can reach other networks of the same group through the group's headquarters. We make the important assumption that the regulatory arrangements between the group headquarter and each local authority are signed through staggered contracts.[16] We motivate this assumption as follows: First, groups are not able to unilaterally decide on the objectives of a fixed-price contract in all networks simultaneously as contract choice is rather the outcome of a negotiation process between the operator and the local authority. Second, contract length varies from one network to another, with an average close to 6 years. Many municipalities prefer to implement even shorter regulatory arrangements, while others are more keen to use long-term regimes that can last for periods of more than 10 years. This makes it even harder for a group to synchronize decisions on the content of the contracts. Finally, note that municipal councils are elected for short period terms which do not necessarily coincide with contract schedules; a change of political color after a new election might for instance lead to a change of operator after a new tender.[17] Overall, this motivates our claim that

[16]The evaluation of the relative social welfare merits of signing staggered or synchronous contracts is outside the scope of this paper. Rey, Iossa and Waterson (2021) suggest that the choice of one arrangement or another should depend on whether the industry is characterized by economies of scale and whether the incumbent enjoys a significant cost advantage with respect to potential competitors.

[17]The choice of regulation in the French transportation industry can be influenced by local interest groups: A local government willing to leave significant rents to the operator's employees may prefer

the group headquarter cannot easily anticipate all the future regulatory outcomes and that a decentralized management of contract choice and effort decisions seems to be a more reasonable assumption.[18] However, it is in the best interest of the headquarters to build experience on local management and transmit the information to all the operators of the group. As a result each operator is assumed to take the efforts of the other operators of the same group as given and there is a unique equilibrium in the effort game of a group, as in Mas and Moretti (2009), for instance. As each operator observes the choice of contract in the other networks, it is able to predict each other choice of effort perfectly.[19]

We now explicitly take into account these incentives through the cost function (1) that is conditional on inefficiency θ and the R&D effort level e. We first derive the optimal level of effort for each operator and check how this effort depends on the incentives generated by the economic environment of the operator. Second, we plug back this level of effort into the conditional cost function. This allows us to generate an unconditional structural cost function that can be estimated with our data.

We assume now that n_g denotes the set of networks that a group g operates under a fixed-price (FP) contract. Under a fixed-price contract, each operator i determines the optimal R&D effort level that maximizes the objective function

a cost-plus contract, since the latter is associated with higher operating costs; on the other hand, an operator's stakeholders looking for large returns may lobby the regulator and the operator to obtain a fixed-price arrangement which should provide higher profits. Gagnepain and Ivaldi (2017) sheds light on how much these ingredients are relevant and shows that a model that accounts for the choice of contract when estimating operating costs performs better compared to a simpler structural cost model. In our current setting, trying to explain the choice of contract for one network would imply accounting for the decisions (including the future ones) of all other networks of the same group. This would complicate drastically our exercise; moreover, we have no information in our data that would allow us to investigate further the negotiation process between the local authority and the operator. For the sake of clarity and ease of exposition we therefore prefer to take contracts as exogenous here.

[18]In order to further support the idea of decentralized innovation, we also note from anecdotal evidence that, although innovation in public transport is carried out by operators, it is very often triggered locally by the public authority in charge of regulating the service. For instance, the use of contactless travel cards by consumers started in the 1990s thanks to the introduction of a new smart card technology and originated in the cities of Nice and Amiens (Ampélas, 2001). Lyon experimented first with the dynamic bus lane an innovation that allows a lane to be reserved in the event of a traffic jam. Dijon has first implemented a system that allows the operator to control the traffic lights of the urban network directly in order to prioritize public transport. More recently, contactless payments, which allow the consumer to buy a ticket without the need for a desk selling got first introduced in Grenoble.

[19]In this context, a less realistic assumption would be that the group headquarter maximizes a joint profit function and decides upon the effort levels for all the operators in the group simultaneously. Such a scenario would probably lead to higher efforts levels overall inside the same group compared to the current setting. From a methodological point of view, it would also create intractable difficulties and would prevent us from deriving a closed-form solution for our cost function.

$$\pi_i = \begin{cases} t_i + R\left(q_i\right) - C_i(C_i^0, \theta_i, e_i|\beta) - \psi\left(e_i, \alpha\right) & \text{if } i \text{ is independent,} \\ t_i + R\left(q_i\right) - C_i(C_i^0, \theta_g, e_{ig}, \kappa_{ig} e_{-ig}|\beta) - \psi\left(e_{ig}, \alpha\right) & \text{if } i \in g, \end{cases} \tag{3}$$

where $R(q) = p(q)q$ denotes revenue, q measures transport demand, and the cost reduction activity e induces an internal cost $\psi(e)$ which is borne solely by the local operator.[20] If the operator is independent, the optimal effort level e_i that maximizes its profit in (3) is determined by the following first order condition:

$$-\frac{\partial C_i(C_i^0, \theta_i, e_i|\beta)}{\partial e_i} = \frac{\partial \psi_i(e_i, \alpha)}{\partial e_i}, \tag{4}$$

which implies that the optimal level of effort e_i is chosen to equalize marginal cost savings with the marginal disutility of effort. In the case of an operator that belongs to a group, the optimal R&D effort level is also influenced by the R&D effort exerted by the remaining members of the group. Each of the operator of group g regulated under a FP contract takes e_{-ig} as given and chooses the optimal e_{ig} that satisfies the first order conditions:

$$-\frac{\partial C_i(C_i^0, \theta_g, e_{ig}, e_{-ig}|\beta)}{\partial e_{ig}} = \frac{\partial \psi_i(e_{ig}, \alpha)}{\partial e_{ig}}, \quad \forall i \in g. \tag{5}$$

Hence, the optimal effort level e_{ig} is conditional on the effort e_{-ig} exerted by the other members of the group:

$$e_{ig} = e_{ig}\left(C_i^0, \theta_g, \kappa_{ig} e_{-ig} \mid \beta, \alpha\right), \quad \forall i \in g. \tag{6}$$

We expect e_{ig} to be decreasing in the effort of the others e_{-ig}. Free-riding naturally arises because the cost of effort is only borne by the local network operator while the effort itself benefits (at least partially) all members of the group. Solving for the n_g equations, we obtain the unconditional effort level:

$$e_{ig} = e_{ig}\left(C_i^0, C_{-i}^0, \theta_g, \kappa_{ig}, n_g|\beta, \alpha\right), \quad \forall i \in g. \tag{7}$$

[20]We distinguish capacity (or supply) Q from demand q. As demand fluctuates during the day, the regulator determines the minimum capacity level that covers all quantities of service requested at any moment of the day. As capacity cannot adjust instantaneously to demand levels, the minimum capacity level is always higher than demand. With these notations, commercial revenues are determined by q, while costs are determined by Q.

Plugging these effort level back into the conditional cost function (2) yields the unconditional cost function.

4 Econometric specification

We now turn to the econometric specification of our cost regulation framework. In order to derive the structural cost function to be estimated, we need to assume a specific functional form for the cost function in (2) and the disutility of effort $\psi(e)$. We assume a Cobb-Douglas specification for the cost function. This specification retains the main properties desirable for a cost function while remaining tractable. Alternative more flexible specifications such as the translog function lead to cumbersome computations of the first order conditions when effort is unobservable. The primal cost expression is therefore specified as:

$$C_i^0 = C_i^0(w_i, Q_i, I_i, K_i|\beta) = \beta_0 w_{L_i}^{\beta_L} w_{M_i}^{\beta_M} Q_i^{\beta_Q} I_i^{\beta_I} K_i^{\beta_K}. \tag{8}$$

We impose homogeneity of degree one in input prices, i.e. $\beta_L + \beta_M = 1$. In order to allow the observed cost C to deviate from the cost frontier defined by (8), we specify the function $\phi(\cdot)$ to be the exponential function, so that (2) is now specified as

$$C_i(C_i^0, \theta, e|\beta) = \begin{cases} C_i^0 \times \exp\{\theta_i - e_i\} & \text{if } i \text{ is independent} \\ C_i^0 \times \exp\{\theta_g - e_{ig} - \kappa_{ig} \sum_{j \neq i} e_{jg}\} & \text{if } i, j \in g. \end{cases} \tag{9}$$

Moreover, the internal cost of effort is given by the following function:

$$\psi\left(e_i\right) = \exp\left\{\alpha e_i\right\} - 1, \quad \alpha > 0, \tag{10}$$

where α is a parameter to be estimated.

Using the specifications for the operating costs (9) and the cost of effort (10), we can solve the first order conditions defined in the previous section to express the optimal effort level for a network under a FP contract. We next determine the effort levels and the resulting unconditional cost functions for the different operators according to their group status.

Independent Operators

For an independent operator i, the optimal R&D effort level under a FP contract is given by the solution to (4) and is expressed as:

$$e_i = \frac{1}{1+\alpha}\left(\ln(C_i^0) - \ln(\alpha) + \theta_i\right). \tag{11}$$

Substituting back e_i into (9) allows us to obtain the final form for the cost function $C_i(\cdot)$ to be estimated for independent operators as:

$$\ln(C_i) = \frac{\alpha}{1+\alpha}\left[\ln(C_i^0) + \theta_i\right] + \frac{1}{1+\alpha}\ln(\alpha). \tag{12}$$

Operators Belong to Industrial Groups

If an operator i belongs to a group, it will benefit from its own cost reducing activity and from the efforts of the $n_g - 1$ remaining operators that belong to the same group and that are regulated under fixed-price regimes. Thus, for any industrial group g where $n_g \geq 2$ and for any $i,\ j \in g$, the unconditional effort level is:

$$\begin{aligned} e_{ig} \quad = \quad & \frac{1}{(1+\alpha+(n_g-1)\,\kappa_{ig})} \times \left[\frac{(1+\alpha+(n_g-2)\,\kappa_{ig})}{(1+\alpha-\kappa_{ig})}\ln(C_i^0)\right. \\ & \left. - \frac{\kappa_{ig}}{(1+\alpha-\kappa_{ig})}\sum_{j\neq i}\ln(C_j^0) + (\theta_g - \ln(\alpha))\right]. \end{aligned} \tag{13}$$

Notice how, for operator i, e_{ig} now depends on the components defining the cost ingredients of the remaining operators of the group, $\sum_{j\neq i}\ln C_j^0$. A higher effort e_{ig} is expected if the operator faces a higher cost C_i^0, which happens for instance in the case of higher input prices w_i. At the same time, shirking by i is likely if the other members of the same group also face high costs C_j^0, i.e., if they exert a significant amount of R&D effort as well. Plugging the optimal efforts (13) back into the cost function (9) allows us to obtain the final form for the cost functions $C_{ig}(\cdot)$ to be estimated. Hence if operator i belongs to group g, then, $\forall\ j \in g$, the final form for the cost function is given by:

$$\ln(C_{ig}) = \frac{\alpha}{(1+\alpha+(n_g-1)\,\kappa_{ig})}\left[\frac{(1+\alpha+(n_g-2)\,\kappa_{ig})}{(1+\alpha-\kappa_{ig})}\ln(C_i^0)\right.$$
$$\left.-\frac{\kappa_{ig}}{(1+\alpha-\kappa_{ig})}\sum_{j\neq i}\ln(C_j^0)+\theta_g\right]+\frac{1+(n_g-1)\kappa_{ig}}{1+\alpha+(n_g-1)\,\kappa_{ig}}\ln(\alpha). \qquad (14)$$

The absorptive capacity parameter κ_{ig} plays a key role in this expression. As κ_{ig} increases, the efforts provided in the remaining networks of the group have a stronger impact on the reduction of the inefficiencies. The coefficient on the θ_g parameter decreases in κ_{ig} : $\frac{\partial}{\partial\kappa_{ig}}\left[\frac{\alpha}{1+\alpha+(n_g-1)\kappa_{ig}}\right] < 0$. Likewise, the negative effect of the inefficiency parameter is reduced when the number of FP networks within the group, n_g, increases, as operator i can benefit from the efforts of a larger number of operators. Note also that $\lim_{\kappa_{ig}\to 0}\ln(C_{ig}) = \ln(C_i)$, as network i only benefits from its own efforts when knowledge spillovers are absent.

Absorptive capacity

We need now to discuss how the identification of the absorptive capacity parameter κ_{ig} unfolds. We suggested above that operators should have in-house knowledge power in order to optimally benefit from R&D spillovers. The knowledge base of each operator is proxied here by a set of variables that account for the characteristics of the transport operator, those of the network where the service is provided, and the identity of the group g who owns the operator. In other words:

$$\kappa_{ig} = \kappa\left(\gamma_g, \delta_i, DIF^x_{i-g}\right), \qquad (15)$$

where γ_g is a group fixed effect which controls for the unobserved group know-how; it measures group g's contribution to the network's capacity to assimilate the knowledge spilled over by the other networks from the group, and δ_i should be seen as a variable that captures the effect of the unobserved network-specific characteristics on κ_{ig}.

Moreover, DIF^x_{i-g} is an index which assesses potential differences in characteristic x between operator i and the average operator of group g (regulated under a FP contract). We thus assume that the different operators of group g enjoy asymmetric absorptive capacity levels. Whether information flows more easily when the features of their operations are more similar or dissimilar is unclear at this stage. Indeed, as noted by Cohen and Levinthal (1990), on the one hand *"learning is cumulative, and learning performance is greatest when the object of learning is related to what is already known. As a result, learning is more difficult in novel domains"*; on the other hand, *"Diversity of knowledge (also) plays an important role. [...] A diverse background provides a more robust basis for learning because it increases the prospect that incoming information will relate to what is already known."* Hence, the sign of the effect of DIF^x_{i-g} on κ_{ig} needs to be tested empirically with our data. We present now our database, the construction of the variables, and the estimation results of the empirical analysis.

5 Empirical Strategy and Results

For an operator i in period t, we estimate the cost function:

$$\ln(C^o_{it}) = \xi^G_{it} \ln(C_{igt}) + \xi^I_{it} \ln(C_{it}) + \varepsilon_{it}, \tag{16}$$

where ξ^G_{it} takes value 1 if operator i belongs to one of the three main industrial groups, and 0 otherwise, while ξ^I_{it} takes value 1 if operator i is independent, and 0 otherwise. In other words, the observed cost C^o_{it} is predicted by two different cost structures, C_{igt} or C_{it}, depending on whether operator i belongs to a group or not. C_{igt} or C_{it} are expressed in Equation (14) and (12) respectively, and κ_{ig} in (14) is given by Equation (15). Both C_{igt} or C_{it} also depend on the same primal cost C^0_i shown in (8), i.e., operators share the same initial technology β independently from whether they belong to a group or not. However, they differ in the inefficiency θ, the absorptive capacity κ, and the effort e. As a result, the two different cost structures in (14) and (12) entail different marginal effect of the explanatory variables w, Q, I, and K on costs C^o_{it}. Thus, instead of assuming a different technology β for each type of operator, which could not be identified in our model, we distinguish two cost structures that allow us to identify how distortions above a common primal technology are built up from the existence or the absence of cost synergies.

We also introduce an error term, ε_{it}, to account for the fact that our Cobb-Douglas technology is potentially a rough approximation of the data reality; moreover, small measurement errors in the database cannot be discarded for some networks. The error term is distributed as a normal density function with mean 0 and variance σ_{ε}^2. The likelihood of a data point defined by a cost level is then

$$L\left(C_{it}^0\right) = L(C_{it}^0 | w_{it}, Q_{it}, I_{it}, K_{it}, \theta_i, \theta_{ig}, DIF_{i-g}^x, n_g, \xi_{it}^G, \xi_{it}^I \mid \alpha, \beta, \gamma_g, \delta_i). \tag{17}$$

Since θ_i and θ_{ig} are unobservable, they will be treated as fixed effects specific to each independent operator or group.[21] Assuming that observations are independent, then the log-likelihood function for our sample is just the sum of all individual log-likelihood functions obtained from Equation (17). Before presenting the estimates of the structural cost function (16), we discuss the construction of the variables of the model.

5.1 Data and Variables

Different types of variables are required in order to identify our model. The cost equation calls for covariates that capture elements of the economic environment, which entails both group-specific and network-specific characteristics.

As in Gagnepain and Ivaldi (2002), estimating the Cobb-Douglas cost function requires information on the level of operating costs, the quantity of output, capital, and the input prices. Total costs C, expressed in real terms, are defined as the sum of labor and material costs. Output Q is measured as the number of seat-kilometers, i.e., the number of seats available in all components of rolling stock times the total number of kilometers traveled on all routes. This measure accounts for the length of the network, the frequency of the service and the size of the fleet. It is also meant to be a measure of the quality of service. Capital K, which plays the role of a fixed input in our short-run cost function, is the size of the rolling stock, which is measured as the total number of seats available. Infrastructure I, which also plays the role of a fixed input, is measured as the total length of the transport network in kilometers. Since the authority owns the capital, the operators do not incur capital costs. The average wage rate w_l is obtained by dividing total labor costs by the annual number of employees. The price of materials w_m has been constructed as the average fuel price for France (published by the

[21]The two inefficiency parameters are independent of time, which is debatable. In a dynamic setting, inefficiency could be interpreted as a cumulative process that evolves over time, and its evolution could be approximated by a trend. (See Cornwell, Schmidt, and Sickles (1990) for such a model). Our attempts in this direction have not been successful.

OECD).[22]

Summary statistics are provided in Table 1 and 2, where we distinguish operators according to their group affiliation. The table illustrates well the fact that independent operators are usually involved in smaller operations compared to those owned by large groups. Moreover, Keolis operates larger networks on average, while Connex operates smaller ones. The three groups however pay similar wages to their employees and their average costs are very close to each other (3.43, 3.28, and 3.31 cents of euro per seat kilometer for Connex, Keolis, and Transdev, respectively).

We also need information on the features of the urban networks and the industrial groups in charge of the transport operations. We construct a dummy variable for each specific network and another dummy for each one of the three industrial groups (Connex, Keolis and Transdev). In order to take into account the fact that different operators from the same group may enjoy asymmetric absorptive capacities, we expect the index DIF^x_{i-g} to be a measure of the difference in the x characteristic between the observed operator i and the average operator under a FP contract in group g, $\bar{x}_g$:

$$DIF^x_{i-g} = \frac{|x_{ig} - \bar{x}_g|}{x_{ig}}.$$

In our estimations, we consider different dimensions x in order to calculate this index. In particular, we will focus on structural differences with respect to the share of drivers and the length of the network. The share of drivers is obtained by dividing the number of drivers in each network by the total labor force, which includes both the bus drivers and the engineers. The size of the network is measured as the total length of the transport network in kilometers. Again, the sample that we use in our estimation is an unbalanced panel composed of 67 different networks regulated under FP contracts and contains 714 observations over the period 1987-2001.

[22]Trying to capture a potential technological progress that affects all operators can be achieved with the introduction of a trend on the right hand side of the equation as well. Identifying such effect has proved problematic as production increases over time in all networks. If technological progress hits more intensively highly innovative operators, the identification of the inefficiency θ, the absorptive capacity κ, and the effort e would become a much more difficult task. However, we are not aware of any anecdotical evidence that could motivate such assumption.

5.2 Results

We turn now to the empirical results of our estimations. The first two columns of Table 3 display the estimates of alternative specifications where different explanatory variables are used as proxies for κ_{ig}, the operator-specific absorptive capacity within each of the industrial groups. We assume a quadratic form for κ in (15):

$$\kappa_{ig} = \left(\gamma_g + \delta_i + \mu DIF_{i-g}^{x}\right)^2. \tag{18}$$

DIF_{i-g}^{x} depends on two dimensions which are the size of the network (Specification I) and the share of drivers (Specification II). On the one hand, network size is an important network feature as it affects the intensity of transport operations in terms of the number of seat-kilometers supplied by the operator, the technology in use (the potential existence of returns to scale and density are important issues in the transportation industry), and external costs as negative externalities produced by private vehicles are more important in larger cities. On the other hand, the share of drivers provides a measure for the endowment of skills embodied in the operator. Workers in the operator are mostly drivers and engineers; engineers are generally responsible for research and development in quality control, maintenance, and efficiency. Their action is particularly important for the improvement of the average speed of the network, which can be considered as one of the most important criteria of modal choice. Improving the commercial speed of transit systems by providing specific infrastructure improvements such as lanes dedicated to buses increasingly concerns transport operators and local authorities.[23]

Most parameters are consistent across each specification; they are usually significant at the 1% level and have the expected sign. Technological process is characterized by constant returns to scale as β_Q is not statistically different from 1. More importantly, DIF_{i-g}^{Len} and DIF_{i-g}^{Dri} both have a positive impact on the absorptive capacity κ_{ig} of the operator. This result suggests that networks that present larger differences in characteristics relative to their group benefit to a larger extent from the efforts provided

[23]The share of drivers could also be a good indicator of the intensity of moral hazard in the contractual relationships between the local regulator and the transport operator. Moral hazard becomes particularly relevant in an operator where drivers represent a large share of the working force since, in this case, the training of employees and the bargaining process with the unions become a key concern.

in the other networks from their group.[24] Thus, while a minimum degree of overlap of knowledge across operators is necessary for internal communication, there are also benefits to diversity of knowledge and organizational structures across networks. This also goes in line with Simon (1985) which emphasizes that diverse knowledge experiences elicit the sort of learning and problem solving that yields innovation. It is key for the industrial groups in charge of transportation services in France to develop an active network of external relationships in order to strengthen each local managers' awareness of others' expertise. As a result, the group's absorptive capacity is increased.

We also tested other potential determinants of the absorptive capacity κ_{ig}. In particular, the geographical distance between two networks could influence the ability of each operator to exploit incoming spillovers. In other words, the diffusion of spillovers could be facilitated among the closest urban networks of the same group as a shorter distance facilitates face-to-face communication and on the spot feedback. As suggested by Figure 1, urban networks of the same group might be clustered in the same geographical area. This is the case for instance of Hénin-Carvin, Lens, and Lille, which are located less than forty kilometers apart from each other in the north of France, and all of them belong to Keolis. To test for this effect, we replace in Equation (18) DIF^{x}_{i-g} by $DISTANCE_{i-g}$. The latter is interpreted as a closeness centrality index which provides information on the geographical position of operator i within the set of all operators that belong to group g (see Wasserman and Faust, 1994, and Bloch, Jackson, and Tebaldi, 2019, for a discussion on key measures in the literature). It is computed as the average of all distances $d(i,j)$ between operator i and other operators j in group g:

$$DISTANCE_{i-g} = \frac{1}{n_g} \sum_{j \neq i} d(i,j). \tag{19}$$

Thus, in that measure, a higher score indicates a lower centrality, i.e., the observed operator is, on average, located further away from the other members of his group, and this in turns should complicate its ability to exploit incoming spillovers. The average distance between two operators of the same group is 362.7 kilometers (356.9, 351.4, and 386.5 for Transdev, Keolis, and Connex, respectively), which casts doubts on the relevance of the geographical effect. Specification III in Table 3 suggests that the effect of

[24]Introducing both DIF^{Len}_{i-g} and DIF^{Dri}_{i-g} at the same time did not produce any significant result. This is most probably due to the fact that the two variables total length and the share of drivers are not entirely independent (the correlation coefficient is -0.49) , which creates potential collinearity.

$DISTANCE_{i-g}$ is nil. Hence, the absorptive capacity of transport operators is mostly built upon diversity of knowledge and experience but does not require operators to be in close geographical positions to each other.

We also estimate each group's intrinsic inefficiency θ_g, which is interpreted as the know-how of the group's engineers who are responsible for R&D, quality control, maintenance, and network design locally. Our estimation results suggest that the θ_gs are positive and significantly different from each other. In both cases, Keolis appears to be the most efficient group (the one with the lowest θ_g), followed by Connex and Transdev. Our estimation procedure also accounts for the inefficiency θ_i of independent operators; the estimated $\hat{\theta}_i$ range from -0.194 to 0.351, which suggests that groups are on average more inefficient than independent operators.[25] Whether this latter results is driven by a selection effect, i.e., independent operators focus on smaller networks which are easier to run, remains to be seen and is outside the scope of this paper. In any case, as suggested by Equation (2), these initial inefficiency levels are partially offset by the effort activity of each operator. Hence, the group distortion $\phi\left(\theta_g, e_{ig}, \kappa_{ig} e_{-ig}\right)$ above the cost frontier $C_i^0(w_i, Q_i, I_i, K_i|\beta)$ could be lower than the distortion $\phi\left(\theta_i, e_i\right)$ of independent operators once the effort effect is taken into account.

To illustrate this latter point, we present in Table 4 the results of an alternative estimation procedure. Specification IV is a cost frontier which includes group (independent resp.) global inefficiency variables ξ_g (ξ_i resp.) but does not account for the effort exerted by operators; the estimated $\hat{\xi}_i$ range from -0.446 to 0.217. In this case, the effort activity of the operators is not explicitly expressed in the structure of the cost frontier but it is embedded in ξ_g and ξ_i. In other words, from Equation (9), $\xi_g \simeq \theta_g - e_{ig} - \kappa_{ig} \sum_{j \neq i} e_{jg}$ and $\xi_i \simeq \theta_i - e_i$ are direct measures of the distortion above the frontier in Specification IV. As expected, $\hat{\theta}_g > \hat{\xi}_g$ and $\hat{\theta}_i > \hat{\xi}_i$. Another interesting result is that the three groups Connex, Keolis, and Transdev are close to the frontier ($\hat{\xi}_g$ is close to 0) while several independent operators are located further away ($\hat{\xi}_i$ is significantly greater than 0). Hence, the joint effort activity of the operators in groups is high enough so that they are able to almost offset their initial exogenous inefficiency. This somehow suggests that the current size of the groups (15, 22, and 19 networks for Connex, Keolis, and Transdev respectively) is relevant from a social point of view, if the main objective is to reduce

[25] We obtain negative $\hat{\theta}_i$s for a limited number of operators; in this case, the total distortion is lower than one. Note that this should not come as a surprise since our cost frontier is stochastic.

cost inefficiency.

We also present in Table 4 Specifications V-VI which are a simple Cobb-Douglas cost function with no effort and no inefficiency. Overall, the estimated parameters are consistent across the different specifications, with the exception of the effect of the infrastructure which is not significant in IV-VI.

$$\kappa_{ig} = \kappa\left(\gamma_g, \delta_i, DIF^{x}_{i-g}\right),$$

With the estimated $\hat{\mu}$ and the individual $\hat{\gamma}_g$ and $\hat{\delta}_i$ in hand, we are able to evaluate $\hat{\kappa}_{ig}$ for each industrial group. Table 5 presents the results derived from specifications I and II. The estimated $\hat{\kappa}_{ig}$s are statistically significant and differ across groups, with larger values for Connex and Transdev compared to Keolis. We know from Equation (15) that $\hat{\kappa}_{ig}$ depends on three main factors, namely the unobserved group g know-how γ_g, the unobserved operator i-specific characteristics δ_i, and an index DIF^{x}_{i-g} which assesses differences in observed characteristic between operator i and the average operator of group g. We note that there is no significant difference in the average DIF^{x}_{i-g} across groups; moreover, as suggested in Table 3, $\gamma_{Connex}<\gamma_{Keolis}$. Hence, the lower $\hat{\kappa}_{ig}$ for Keolis is mostly driven by the unobserved characteristics of the operators that are members of the group. We indicated above that Connex and Transdev benefit from a higher quantity of networks regulated under FP contracts in France compared to Keolis, which might help each one of them to develop cumulative absorptive capacity (Cohen and Levinthal, 1990). Unfortunately, without more detailed information on operators' internal management in our data, we are not able to investigate more seriously the reasons why Keolis suffers from a lower absorptive capacity.

6 Counterfactual organization

Our model predicts that operator i of group g will benefit from the efforts exerted by the other operators in the group, conditional on the absorptive capacity κ_{ig}. We propose now a counterfactual exercise which aims at appraising the total cost reduction effect of adding extra operators to a group. The simulation exercise works as follows:

1. For each group g, we calculate the average absorptive capacity $\overline{\kappa}_g = \frac{1}{n_g}\sum_{i\in g}\hat{\kappa}_{ig}$,

$g = \{Connex,\ Keolis,\ Transdev\}$.

2. The average operator of group g has average characteristics $C_g^0(\overline{w}, \overline{Q}, \overline{I}, \overline{K} | \hat{\beta})$ and $\overline{\kappa}_g$.

3. For each group g, we compute costs differentials which depend on the number of *average* operators included in the group. The simplest structure possible is the one where g contains only one average operator with operating cost given by (12). Increasing the size of the group g by p units consists in introducing p additional average operators with the same characteristics as the ones defined in 2; the individual cost beard by the $1 + p$ operators in g is given by the cost expression (14). Our final aim is to compute, for each group g, the cost differential in percentage associated with the increase in the group size from n_0 to $n_0 + p$ average operators, $n_0 \geqslant 1$, and $p > n_0$. In other words, we calculate for each group g:
$$\triangle_{n_0}^{p} C_g \equiv \frac{(C_g \mid n_g = n_0 + p) - (C_g \mid n_g = n_0)}{(C_g \mid n_g = n_0)} \times 100. \tag{20}$$

Tables 6 to 8 present the results of this simulation exercise for Connex, Keolis, and Transdev, respectively, using the estimates of specification II. In each Table, n_0 and $n_0 + p$ are the row and column names respectively: For instance, in the Connex group (Table 6), the cost effect of switching from 2 to 5 operators is -12.03%.

Several interesting results are worth noticing. First, most cost reductions presented in these tables are statistically significant; being in a group of at least two operators yields a higher cost reduction compared to a situation where both operators remain independent. Second, as expected, costs reductions increase with the number of participants in each group and can be quite important: An isolated Keolis operator joining a group of ten other operators would reduce costs by 12.48%. Third, the marginal cost reduction decreases in the size of the group. Take the case of Keolis for instance: Switching from one to two participants allows each group member to reduce their costs by 1.62% each; at the same time, switching from nine to ten participants allows a 1.5% cost reduction for each of them. Finally, each group benefits from the inclusion of additional operators to different extent, conditional on their absorptive capacity. Table 5 indicates that Connex and Transdev enjoy the largest absorptive capacities, which allows them to obtain higher cost reductions compared to Keolis. Over our period of observation, Connex, Keolis, and Transdev run services in 15, 22, and 19 networks respectively. Increasing the current number of networks by one unit would allow them to decrease their cost by 3.44, 1.32, and 2.84% respectively.

Interestingly, the last important merger that was witnessed in the French transport industry occurred in 2011 and involved precisely Connex (renamed Veolia Transport) and Transdev. Simulating the effect of this merger in terms of cost reductions is out of the scope of this paper given that the merger period does not coincide with our data, but our model provides a potential insight of this effect: As Connex is the group that enjoys the highest absorptive capacity, and Transdev is the group with the largest number of networks, Connex may be the largest beneficiary of the merger operation. Note also that the usual merger simulation exercise sheds light on the trade-off between a potential cost reduction after the merger and a price increase due to less ex ante competition. While previous papers working on this issue have mostly discussed the demand side of the analysis (Davis and Garcés, 2009), our model is a potential contribution to the cost side. Our results emphasize that, in network industries where the same operator operates several services simultaneously, cost savings are potentially important.

7 Conclusion

Technological change and the diffusion of new technologies are relevant issues in urban transportation in Europe (Costa and Fernandes, 2012). In this paper, we identify and evaluate the presence of knowledge spillovers that flow across French urban transport operators. We build and estimate a structural cost regulation model with asymmetric information that includes operators' individual efficiency plus their absorptive capacity which conditions their ability to process incoming information and experience from other networks. Our results suggest that the flow of knowledge spillovers across the members of the same group are significant and increase with the size of the group, and they allow transport operators to obtain significant cost reductions.

We take advantage of two specific features of the industry which do not pertain to the French case only but are instead common to most developed countries: First, most of the operators that provide the transport services locally are owned by large industrial groups. Thus, the same productive units are present simultaneously in several urban networks, which allows them to build a know-how at the group level based on their own local expertise. Second, a particularity of the service is that it is affected by negative externalities, e.g. traffic congestion, that are directly monitored by local authorities: As a result, technology is often driven by the concomitant decisions/actions of both local authorities and transport operators, which explains why technological improvements should be seen as shocks that originate locally and then spread across the urban networks of the same industrial group. On the contrary, in other public services such as water or energy distribution, the improvement of technology is rather under the sole responsibility of the firms in charge of the operation.

To conclude, we note that the economic literature is almost unanimous on the fact that the incentive power of the contracts used by public authorities in charge of the organization of public services has a significant effect on the operators' costs (Gagnepain and Ivaldi, 2020). This article suggests that combining the cost-reducing activities of several operators regulated under fixed-price contract allows them to enjoy even stronger cost-reductions, compared to an industrial organization where the exchange of information is absent. Hence, fixed-price contracts are efficient tools for cost efficiency, and it is even more important to implement them in different networks at the same time in order to benefit from knowledge spillovers.

From a social point of view, it is thus probably in the interest of the central government to promote the implementation of fixed price contracts in the French transport industry and guarantee a significant market power to transport groups in order to allow them to be present in several networks. As structural differences across operators/networks is an important driver of absorptive capacity, these groups should be incentivized to take control of networks with different characteristics, i.e., geographical clusters of networks operated by the same group should be avoided as much as possible. In practice, a simple recommendation would then be to foster ex ante competition in areas where geographical clusters are observed. If a more concentrated industry is not acceptable, another solution could consist in facilitating information flows between the local operators, whether or not they belong to the same group, through an industry-level research joint venture. More in general, whether a more concentrated industry guarantees sufficient efficiency gains that offset the loss of competition remains to be tested. Gagnepain and Martimort (2016) indicates that, in the case of the merger between Veolia Transport and Transdev, the loss in competition would have been outweighted by a minimum of 18% efficiency gains. The results obtained here suggest that this statistic is a realistic target.

Finally, another potentially interesting issue to be tested is whether local tenders should be organized at the same time in the whole industry. Currently, local governments and operators negotiate regulatory objectives through staggered contracts, which does not facilitate the ability of the headquarters to coordinate local decisions on R&D expenditures. Empirical evidence showing that simultaneous tenders are welfare improving would probably argue again in favor of the establishment of a national transport regulator with enough expertise in France.

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Figure 1: Networks

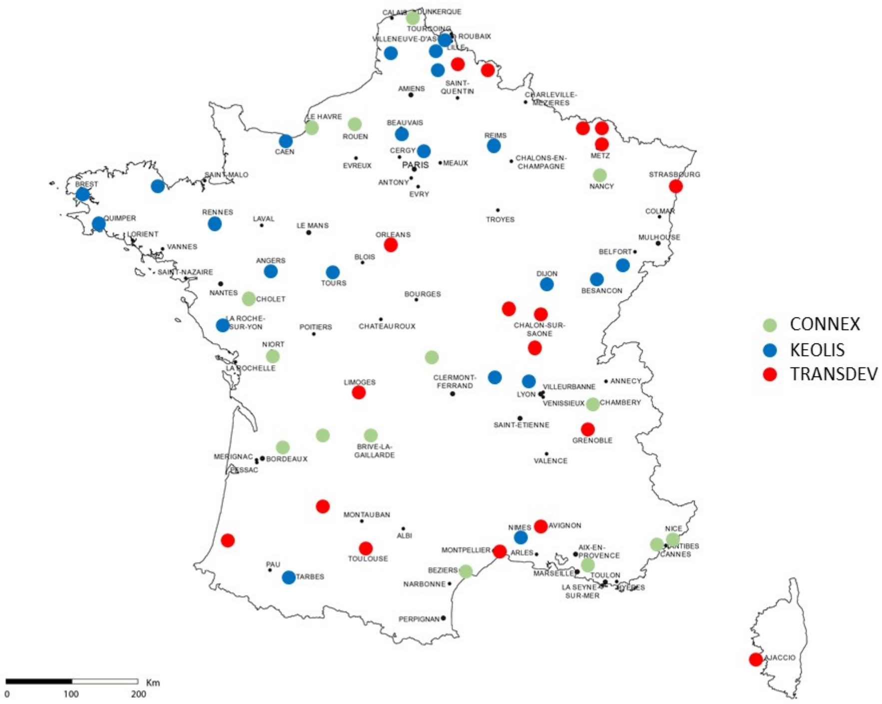

Table 1: Summary statistics by type of operator (1987-2001)

		Type of operator			
		Belongs to group		Independent	
Name	Variable	Mean	Std dev.	Mean	Std dev.
Cost (Euros$\times 1000$)	C	18,157	26,883	6,473	5,261
Revenue (Euros$\times 1000$)	$R(q)$	8,400	13,322	2,765	2,299
Production (Seat-kilometers$\times 1000$)	Q	579,179	748,774	240,942	181,420
Wage (Euros$\times 1000$)	w_L	29.6	5.7	29.1	6.4
Price of materials (Index)	w_M	1.17	0.2	1.18	0.20
Size of the network (Kilometers)	$length$	256	224	153	87
% of drivers in the labor force	$Drive$	0.72	0.08	0.74	0.07

Note: Group refer to operators belonging to either Keolis, Transdev or Connex.

Table 2: Summary statistics by Group (1987-2001)

	Connex		Keolis		Transdev	
Variable	Mean	Std dev.	Mean	Std dev.	Mean	Std dev.
C	17,626	21,559	26,375	44,968	18,647	20,216
$R(q)$	7,901	9,990	12,284	22,814	8,946	9,760
Q	513,129	606,520	803,569	1,247,705	563,414	506,973
w_L	30.6	5.8	29.7	7.4	29.8	4.2
w_M	1.2	0.2	1.2	0.2	1.17	0.2
$length$	233	230	331	314	267	181
$Drive$	0.73	0.06	0.71	0.09	0.70	0.06

Table 3: Structural Estimation Results

Name	Parameter	I	II	III
Constant	$\ln(\beta_0)$	-3.648^{***}	-3.684^{***}	-3.695
		(0.112)	(0.109)	(0.100)
Fixed-effect Connex	θ_{Connex}	0.545^{***}	0.522^{***}	0.511^{***}
		(0.063)	(0.052)	(0.053)
Fixed-effect Keolis	θ_{Keolis}	0.418^{***}	0.374^{***}	0.372^{***}
		(0.044)	(0.046)	(0.046)
Fixed-effect Transdev	$\theta_{Transdev}$	0.630^{***}	0.607^{***}	0.593^{***}
		(0.057)	(0.053)	(0.054)
Wage	β_L	0.279^{***}	0.273^{***}	0.277^{***}
		(0.041)	(0.034)	(0.033)
Production	β_Q	1.042^{***}	1.059^{***}	1.055^{***}
		(0.199)	(0.148)	(0.118)
Infrastructure	β_I	0.124^{***}	0.145^{**}	0.149^{**}
		(0.023)	(0.021)	(0.019)
Cost of effort	$\ln(\alpha)$	1.719^{*}	1.624^{**}	1.633^{**}
		(1.050)	(0.708)	(0.567)
Fixed-effect Connex	γ_{Connex}	-0.242^{**}	-0.225^{***}	-0.219^{***}
		(0.112)	(0.070)	(0.053)
Fixed-effect Keolis	γ_{Keolis}	-0.119^{*}	-0.068^{**}	-0.061^{***}
		(0.069)	(0.031)	(0.023)
Fixed-effect Trans	γ_{Trans}	-0.121	-0.076^{*}	-0.061^{**}
		(0.074)	(0.039)	(0.027)
Dif Length	DIF_{i-g}^{Len}	0.008^{**}		
		(0.003)		
Dif Drivers	DIF_{i-g}^{Dri}		0.072^{***}	
			(0.024)	
Geographical Distance				0.100
				(0.376)
Stand. Dev. error	σ_ϵ	0.102^{***}	0.104^{***}	0.105^{***}
		(0.003)	(0.003)	(0.002)
Ind. Firms fixed effects		*yes*	*yes*	*yes*
Firms fixed effects in κ_{ig}	δ_i	*yes*	*yes*	*yes*
Log-likelihood		1.766	1.759	1.757
Number of observations		714	714	714

Note: Standard errors in parenthesis. ***: Significant at 1%, **: Significant at 5%, *: Significant at 10%.

Table 4: Structural Estimation Results

Name	Parameter	IV	V	VI
Constant	$\ln(\beta_0)$	-4.577^{***}	-4.542^{***}	-4.773^{***}
		(0.120)	(0.118)	(0.121)
Wage	β_L	0.282^{***}	0.283^{***}	0.311^{***}
		(0.034)	(0.034)	(0.035)
Production	β_Q	0.988^{***}	0.988^{***}	0.998^{***}
		(0.012)	(0.013)	(0.012)
Infrastructure	β_I	0.022	0.021	0.021
		(0.017)	(0.017)	(0.017)
Fixed-effect Connex	ξ_{Connex}	0.084^{*}		
		(0.045)		
Fixed-effect Keolis	ξ_{Keolis}	0.042		
		(0.045)		
Fixed-effect Transdev	$\xi_{Transdev}$	0.025		
		(0.044)		
Stand. Dev. error	σ_ϵ	0.203^{***}	0.204^{***}	0.217^{***}
		(0.005)	(0.005)	(0.005)
Ind. Firms fixed effects		*yes*	*yes*	*no*
Log-likelihood		1.078	1.089	1.026
Number of observations		714	714	714

Note: Standard errors in parenthesis. ***: Significant at 1%, **: Significant at 5%,
*: Significant at 10%.

Table 5: Average Absorptive Capacity by Group

	Specification	
Group	I	II
Connex	0.017	0.015
	(0.001)	(0.001)
Keolis	0.007	0.005
	(0.000)	(0.000)
Transdev	0.014	0.012
	(0.000)	(0.000)

Note: Each cell represents the average absorptive capacity of the corresponding group, computed as $\bar{\kappa}_g = \frac{1}{n_g}\sum_{i\in g}\hat{\kappa}_{ig}$. Standard errors are in parenthesis.

Table 6: Percentage change in total costs from adding new operators for Connex

		... to $n_0 + p$ operators in the Connex group								
		2	3	4	5	6	7	8	9	10
Going from n_0 operators...	1	−4.51	−8.58	−12.28	−15.65	−18.74	−21.58	−24.19	−26.62	−28.86
		(0.317)	(0.587)	(0.821)	(1.023)	(1.120)	(1.353)	(1.488)	(1.608)	(1.715)
	2	-	−4.40	−8.39	−12.03	−15.35	−18.40	−21.21	−23.80	−26.21
		-	(0.306)	(0.568)	(0.796)	(0.994)	(1.167)	(1.319)	(1.454)	(1.573)
	3	-	-	−4.30	−8.22	−11.79	−15.06	−18.07	−20.85	−23.42
		-	-	(0.295)	(0.550)	(0.772)	(0.966)	(1.136)	(1.287)	(1.420)
	4	-	-	-	−4.21	−8.04	−11.56	−14.78	−17.75	−20.50
		-	-	-	(0.285)	(0.533)	(0.749)	(0.939)	(1.107)	(1.255)
	5	-	-	-	-	−4.12	−7.88	−11.33	−14.51	−17.44
		-	-	-	-	(0.276)	(0.516)	(0.728)	(0.914)	(1.078)
	6	-	-	-	-	-	−4.03	−7.72	−11.11	−14.25
		-	-	-	-	-	(0.267)	(0.501)	(0.707)	(0.889)
	7	-	-	-	-	-	-	−3.94	−7.57	−10.90
		-	-	-	-	-	-	(0.258)	(0.486)	(0.687)
	8	-	-	-	-	-	-	-	−3.86	−7.42
		-	-	-	-	-	-	-	(0.250)	(0.472)
	9	-	-	-	-	-	-	-	-	−3.78
		-	-	-	-	-	-	-	-	(0.243)

Note: Each cell in the table presents the average percentage change in costs following the addition of p networks to a group in which n_0 operators are already present: $\triangle^p_{n_0} C_g \equiv \left[\frac{(C_g|n_g=n_0+p)-(C_g|n_g=n_0)}{(C_g|n_g=n_0)}\right] \times 100$, using equation (14) in the text.

Standard errors in parenthesis. Estimates are computed from the results obtained in specification II.

Table 7: Percentage change in total costs from adding new operators for Keolis

		... to $n_0 + p$ operators in the Keolis group								
		2	3	4	5	6	7	8	9	10
Going from n_0 operators...	1	-1.62	-3.17	-4.66	-6.09	-7.47	-8.79	-10.06	-11.29	-12.48
		(0.112)	(0.216)	(0.313)	(0.403)	(0.487)	(0.565)	(0.639)	(0.708)	(0.773)
	2	-	-1.60	-3.14	-4.62	-6.04	-7.40	-8.72	-9.98	-11.21
		-	(0.110)	(0.213)	(0.308)	(0.397)	(0.480)	(0.557)	(0.630)	(0.699)
	3	-	-	-1.59	-3.11	-4.58	-5.99	-7.34	-8.65	-9.90
		-	-	(0.109)	(0.209)	(0.303)	(0.391)	(0.473)	(0.550)	(0.622)
	4	-	-	-	-1.57	-3.08	-4.54	-5.93	-7.28	-8.58
		-	-	-	(0.107)	(0.206)	(0.298)	(0.385)	(0.466)	(0.542)
	5	-	-	-	-	-1.56	-3.06	-4.50	-5.88	-7.22
		-	-	-	-	(0.105)	(0.203)	(0.294)	(0.379)	(0.459)
	6	-	-	-	-	-	-1.54	-3.03	-4.46	-5.83
		-	-	-	-	-	(0.103)	(0.199)	(0.289)	(0.374)
	7	-	-	-	-	-	-	-1.53	-3.00	-4.42
		-	-	-	-	-	-	(0.101)	(0.196)	(0.285)
	8	-	-	-	-	-	-	-	-1.52	-2.98
		-	-	-	-	-	-	-	(0.100)	(0.193)
	9	-	-	-	-	-	-	-	-	-1.50
		-	-	-	-	-	-	-	-	(0.098)

Note: Each cell in the table presents the average percentage change in costs following the addition of p networks to a group in which n_0 operators are already present: $\triangle^p_{n_0} C_g \equiv \left[\frac{(C_g|n_g=n_0+p)-(C_g|n_g=n_0)}{(C_g|n_g=n_0)}\right] \times 100$, using equation (14) in the text.

Standard errors in parenthesis. Estimates are computed from the results obtained in specification II.

Table 8: Percentage change in total costs from adding new operators for Transdev

		... to $n_0 + p$ operators in the Transdev group								
		2	3	4	5	6	7	8	9	10
Going from n_0 operators...	1	-3.77	-7.29	-10.58	-13.66	-16.54	-19.25	-21.80	-24.20	-26.46
		(0.151)	(0.288)	(0.412)	(0.525)	(0.627)	(0.720)	(0.804)	(0.881)	(0.952)
	2	-	-3.71	-7.18	-10.42	-13.47	-16.32	-19.00	-21.53	-23.90
		-	(0.148)	(0.282)	(0.404)	(0.514)	(0.615)	(0.706)	(0.790)	(0.866)
	3	-	-	-3.66	-7.08	-10.28	-13.28	-16.10	-18.76	-21.26
		-	-	(0.145)	(0.276)	(0.395)	(0.504)	(0.603)	(0.693)	(0.776)
	4	-	-	-	-3.60	-6.97	-10.13	-13.10	-15.89	-18.52
		-	-	-	(0.142)	(0.270)	(0.387)	(0.494)	(0.592)	(0.681)
	5	-	-	-	-	-3.546	-6.87	-9.99	-12.92	-15.68
		-	-	-	-	(0.139)	(0.265)	(0.380)	(0.485)	(0.581)
	6	-	-	-	-	-	-3.49	-6.77	-9.85	-12.75
		-	-	-	-	-	(0.136)	(0.259)	(0.372)	(0.475)
	7	-	-	-	-	-	-	-3.44	-6.67	-9.71
		-	-	-	-	-	-	(0.133)	(0.254)	(0.365)
	8	-	-	-	-	-	-	-	-3.39	-6.58
		-	-	-	-	-	-	-	(0.130)	(0.249)
	9	-	-	-	-	-	-	-	-	-3.34
		-	-	-	-	-	-	-	-	(0.127)

Note: Each cell in the table presents the average percentage change in costs following the addition of p networks to a group in which n_0 operators are already present: $\triangle^p_{n_0} C_g \equiv \left[\frac{(C_g|n_g=n_0+p)-(C_g|n_g=n_0)}{(C_g|n_g=n_0)}\right] \times 100$, using equation (14) in the text.

Standard errors in parenthesis. Estimates are computed from the results obtained in specification II.