As future contingencies may be difficult to predict at the moment the contract is designed, the regulatory contract is likely to be incomplete. As stated by Williamson (2002), “all complex contracts are unavoidably incomplete. For this reason, parties will be confronted with the need to adapt to unanticipated disturbances that arise by reason of gaps, errors and omissions in the original contract.” An agent may engage in opportunistic behavior *ex ante* in order to win the contract, by anticipating that it will be able to re-negotiate *ex post* terms not covered by the contract (see Prager 1990). Unforeseen costs related to the re-negotiation of the contract may occur.

Transactions costs may be an issue in the French transport industry. As pointed out by Yvrande-Billon (2006), a number of uncertainties may arise that make it hard for local authorities to commit not to change certain terms of contracts. Consequently, renegotiations may occur throughout the duration of the contract. As provided in Cour des Comptes (2005), contracts awarded for the performance of complex operations give rise to difficulties leading to additional costs during their execution.

In the presence of transaction costs, the choice of one contract over another (cost-plus *versus* fixed-price) may be dictated by the complexity of the project. Bajari and Tadelis (2001) consider *ex post* changes related to contract re-negotiations. They suggest the main problem the principal faces when delegating a task to an agent are in fact *ex post* re-negotiations. In line with this view, they develop a model that incorporates moral hazard and transaction costs related to contractual design and re-negotiations. Restricting their analysis to two types of contracts (fixed-price and cost-plus), they shed light on when each type of contract should be used. They show that complex tasks (more costly to design) will be accompanied by a high probability of *ex post* adaptations. These will be delegated using cost-plus contracts. On the other hand, simpler tasks (less costly to design) will be accompanied by a small probability of *ex post* adaptations. These are best administered using fixed-price contracts that provide cost-reducing incentives.

We test whether these findings hold in our industry setting and introduce the following proposition:

Proposition 5 *Cost-plus contracts are preferred to fixed-price contracts when a network is more complex.*

4 Empirical model

4.1 Empirical strategy

Our goal is to estimate the impact of regulatory contract choice on operators’ cost efficiency. Our empirical investigation begins by estimating a function of operating costs on a set of variables that shift costs, taking the following form:

$$C = \xi FP + \beta \mathbf{X} + \alpha + \varepsilon \tag{1}$$

where FP is the regulatory contract choice in place, $\mathbf{X}$ is a vector of exogenous controls, and α are network fixed effects. β and ξ are the parameters to be estimated, where the latter measures the shift in operating costs from cost-plus to fixed-price regimes within a network. Finally, ε is the stochastic error term.

An econometric problem arises when the contract type in place is endogenous. In order to obtain an unbiased estimate of the impact of regulatory choices on cost efficiency by accounting for the endogeneity of contract type, we introduce an endogenous treatment-regression model (see Heckman 1976; Maddala 1983; Greene 2012). Given that FP is an endogenous dummy variable, the empirical task is to use the observed variables to estimate the regression coefficients β, while controlling for selection bias induced by non-random treatment assignment into regulatory regimes. Consequently, FP is introduced in the model expressed in Eq. 1 as a binary endogenous variable that is assumed to stem from an unobservable latent variable:

$$FP* = \gamma \mathbf{Z} + \delta \mathbf{X} + \eta \tag{2}$$

The value of FP is taken according to the rule:

$$FP = \begin{cases} 1 & if\ FP^* > 0 \\ 0, & otherwise. \end{cases} \tag{3}$$

$\mathbf{Z}$ is a vector of variables that explain regulatory contract choices. The error terms (ε,η) are assumed to be correlated bivariate normal with $Var(\varepsilon) = \sigma^2$, $Var(\eta) = 1$ and $Cov(\varepsilon, \eta) = \rho\sigma$.

4.1.1 Cost function

Our econometric strategy involves specifying an underlying cost function for urban transport services. We take an econometric approach to estimating frontiers that uses a parametric representation of technology, pioneered by Aigner et al. (1977) and Meeusen and den Broeck (1977). In particular, we use a fixed-effects methodology allowing the cost function to have a different intercept for different transport networks, exploiting the time-series properties of the data. In addition, we do not restrict cost changes to follow a particular time pattern for all firms (e.g. Schmidt and Sickles 1984; Cornwell et al. 1990; Kumbhakar 1990). Further, in contrast to other models (e.g. Kumbhakar et al. 1991; Battese and Coelli 1993) we do not make specific distributional assumptions for the composite error terms. Our approach is similar to that taken by Ng and Seabright (2001) in the study of the costs of providing air transport services.

Building on Equation 1, costs are modeled by the deterministic total cost function (giving the efficient level of costs) and a second term that reflects inefficiencies. Our hypothesis is that the second term can be broken down to (1) a term that varies across transport networks but is invariant across time and (2) a term that reflects changes in contractual choices, which can vary across networks and across time. Accordingly, we introduce the following cost function:

$$\begin{aligned} C_{it} &= C(X_{it}; \beta) + (\alpha_i + \xi FP_{it}) + \varepsilon_{it} & (4) \\ &= C(Y_{it}, P_{it}, t_t; \beta) + (\alpha_i + \xi FP_{it}) + \varepsilon_{it}, & (5) \end{aligned}$$

where $C(.)$ is the deterministic cost function, Y_{it} is a vector of output, P_{it} represents a vector of input prices, and α_i are firm specific shifts. Moreover, FP_{it} is introduced to capture the contract type under which a network is regulated at a given period. Finally, t is a time trend. β, α, ξ are the parameters to be estimated. The subscript i $(i = 1, \ldots, I)$ indexes the urban transport networks and t indexes time $(t = 1, \ldots, T)$. We assume that operating costs can be represented by a restricted transcendental logarithmic cost function, defined by Christensen and Greene (1976).[11] For network i at time t, the cost function is the following:

$$
\begin{aligned}
ln\left(\frac{C_{it}}{PM_{it}}\right) = {} & (\beta_Y lnY_{it} + \beta_O ln\frac{PO_{it}}{PMit} + \beta_L ln\frac{PL_{it}}{PM_{it}} \\
& + \beta_{YO} lnY_{it} ln\frac{PO_{it}}{PM_{it}} + \beta_{YL} lnY_{it} ln\frac{PL_{it}}{PM_{it}} \\
& + \beta_{LO} ln\frac{PL_{it}}{PM_{it}} ln\frac{PO_{it}}{PM_{it}} + \frac{1}{2}\beta_{LL} ln\frac{PL_{it}}{PM_{it}} ln\frac{PL_{it}}{PM_{it}} + \frac{1}{2}\beta_{YY} lnY_{it} lnY_{it} \\
& + \frac{1}{2}\beta_{OO} ln\frac{PO_{it}}{PM_{it}} ln\frac{PO_{it}}{PM_{it}} + \beta_t t_t) \\
& + (\alpha_i + \zeta FP_{it}) + \varepsilon_{it},
\end{aligned} \tag{6}
$$

where the normalization of operating costs C_{it}, the price of labor PL_{it}, and the price of overhead PO_{it} with respect to the price of materials PM_{it} imposes homogeneity of degree one in input prices.

4.1.2 Endogenous regulatory contract choices

Accounting for the endogeneity of contract type involves introducing in the model FP^*_{it} as a binary endogenous variable that is assumed to stem from an unobservable latent variable. For a given transport network i and time t:

$$FP^*_{it} = FP(O_{it}, POL_{it}, N_{it}, t; \gamma) + C(X_{it}; \delta) + \eta_{it}, \tag{7}$$

where O_{it} reflects operators' group and legal identity, P_{it} represents our political variables, N_{it} captures network complexity, and t is a time trend. Moreover, we include variables X_{it} determining costs from the previous Equation 5.

We next present the data and comment on the construction of variables that enter the model.

4.2 Data and variables

Our study uses a 16-year panel of 126 urban public transport networks in France between 1995 and 2010, with a total of 1,351 observations. The database was created from an annual survey conducted by the Centre d'études et d'expertise sur les risques,

[11] In our empirical investigation, we perform a test to verify whether the transcendental logarithmic cost function is a good representation of the cost structure of transport operators in our study.