民間投資運輸建設之管理代理、產品特性與激勵契約研擬
Management Agency, Product Characteristics and Incentive Contracting in Transport Infrastructure Privatization

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摘　要

本研究針對開發型運輸建設民營化過程中，高階經營團隊所可能引發的資訊不對稱現象，進行激勵契約設計的理論與實證分析。在理論模式的建構方面整合多項工作與共同代理課題，並就運輸服務與不同地產開發服務間的替代性，推導最適激勵契約設計的環境與策略。建模中發現在資訊不對稱下，委託人(設為 n 位)若採分開治理下，其激勵制約能力將為聯合治理模型之 n 分之一；而若委託人分別採行正向競爭且摒除罰則的激勵設計，其制約能力將高於聯合治理模型，且當服務間具完全替代性時，其制約能力更將與資訊對稱下相同，達成最佳解。在實證分析中則以所推導的理論模式為基礎，採用 Probit 模式就所蒐集的全球 58 個 BOT 運輸計畫案進行橫斷面計量經濟分析。實證中發現當運輸服務與地產開發服務間具互補性時，董事會應給予低制約力的激勵，而政府則應給予高制約力的激勵條件。另當各項工作間的不確定具高度相關時，則應給予高階經營團隊較低制約力之激勵。此乃因正相關將增益其風險與所需之保險，而負相關則適可分散其風險。

ABSTRACT

This study codifies and relates critical executive incentive-contracting issue to the unique principal-agent circumstances generated from privatization of development-related transport infrastructure. It provides a framework for designing incentive contract. In the mathematical concept, an integrated multitask agency and common agency were modeled. The outcome could be simplified as: the equilibrium with n principals is exactly as if there is just one hypothetical principal with an objective function that is the sum of all the separate principals' objectives, but the agent's risk aversion is multiplied n-fold. Remember that the more risk averse the agent, the lower the power of the incentive scheme. Thus, the Nash equilibrium incentive scheme with n principals has, roughly speaking, only (1/n)-th the power of the second-best scheme that would be offered by one truly unified principal. With promotion of incentive competition among the Government and the Board the incentives can be more powerful than those in the second-best. In empirical explorations, evidences show first that when transport service consumers view the output of tasks as complementary, CEOs should be given lower-powered incentives from the Board and higher-powered incentives from the Government. Second, when uncertainty across tasks is highly correlated, CEOs should also be given lower powered incentives. A positive relationship increases their risk and therefore their need for insurance. A negative relationship, in contrast, is a source of risk diversification. All of these predictions are confirmed by the empirical data.

關鍵詞：運輸建設、民營化、多項工作代理、共同代理、替代性、互補性、激勵契約

Key Words: Transport Infrastructure, Privatization, Multitask Agency, Common Agency, Substitutes, Complements, Incentive Contracts

I. INTRODUCTION

As a transport infrastructure is decided to be privately delivered, the principals, mainly government and franchise board of directors in this study, must decide who the CEO should be and what incentive contracts to offer. During the selection and the subsequent relationship with franchise CEO, board of directors and government will have incomplete information as to his credentials for the position and (post selection) performance. And, in a development type transport project the infrastructure is mainly served to anticipate real property development. Sometimes they are financially dependent on contributions from government or land developers. There exists occasions where transportation service and property development could: cross subsidized to each other, change capital structure and project returns, reverse CEO's efforts (due to different risks and returns between services), and distort the resources related to the transport project operation and management. The incentive contracts will then be designed on the basis of regulation, subsidy policy, investment returns, capital structure, CEO's efforts, and the behavior information being exposed.

This study combines the topics of private transport delivery, agency theory, and executive compensation to analyze the incentive contracting issues in a game with common agency and multitask agency. The goal to analyze the incentive designation is to provide insight that is useful for board of directors and government to construct efficient and complete incentive contracts with the franchise chief executive officer (CEO).

Empirical contracts of transport projects are collected by means of interview, questionnaire, and from major journals that cover news or events of private provision of transport infrastructure as well as secondary sources from case studies. Due to very few projects are having unified monitoring committee, empirical exploration on common agency issue is very difficult to be conducted. Therefore, only separated monitoring is empirically explored. To verify argument in low powered incentive with agency problems, samples of Build-Operate-Transfer (BOT) transport projects for incentive contracts are selected both from the viewpoints of the Board and the Government. Econometric study results are compared.

II. STATIC INCENTIVE MODELLING

Combines the models of Holmström and Milgrom (1990, 1991), Bernheim and Winston (1986), and Dixit (1996), we assuming the privatized transport franchise CEO controls an *m*-dimensional vector of effort *e*. This yields an *m*-dimensional output vector *x*, which is most simply modelled as effort plus an error term such as $x = e + \varepsilon$ (1)
where the random vector is normally distributed with zero mean and diagonal variance matrix Ω.

We assume that the principals (in our case mainly the Government and the Board) are all risk-neutral; so their benefit functions are linear. Write $b^{j\,\prime} x$ for the benefit function of the *j*-th principal; the superscript *j* identifies the principal, and the prime denotes the transpose of the vector. Let *b* be the sum of the b^j, so the aggregate benefit of all the principals is $b'x$. It is even possible for some components of some of the vectors b^j to be negative, that is, some principals may be harmed by some dimensions of the output, but we will assume that output from franchised infrastructure is beneficial for the group of principals as a whole, that is, $b \gg 0$. The CEO's utility function has constant risk-aversion r and: $u(y) = -exp(-ry)$ (2)
where *y* equals money income minus a quadratic cost of effort, $\frac{1}{2}\, e'\, C\, e$. The matrix *C* is assumed to be positive definite, and with positive cross-partials. Thus, the marginal cost of making one type of effort increases with the level of any type of effort. Therefore, an inducement to increase one type of effort causes substitution away from other types. This creates for each principal an interest in all dimensions of the effort of the CEO, even if he has no direct interest in (benefit from) the outcome of those dimensions.

Let Γ denote the matrix inverse of *C*. It is positive definite, so its diagonal terms are positive. If $m = 2$, it is easy to verify that the off-diagonal terms in Γ are negative. If $m > 2$, some off-diagonal terms may be positive, but the general tendency is for them to be negative. This is exactly like the well-known relationship in consumer-choice theory between complements and substitutes in the quantity (Allen) sense and the price (Hicks) sense. When discussing the results below, we will proceed treating the off-diagonal terms in Γ as negative. An extreme case is one where the matrix *C* has the same scalar entry *k* in all positions, so efforts are perfect substitutes and $e'\, C\, e = k\, [\, \Sigma_{j=1}^{m} e_j\,]^{2}$.

II-A. FIRST-BEST WITH OBSERVABLE EFFORT

If effort can be monitored directly, the principals and the CEO can write contracts contingent on the CEO's making a stipulated effort *e* in return for a payment *z*. The expected return to the principals will be $E[\,b'\,(e+\varepsilon)] - z = b'\,e - z$ and the CEO's utility will be $-exp\{-r(z - \frac{1}{2}\, e'\, C\, e)\}$.

Then, the CEO maximizes $z - \frac{1}{2}\, e'\, C\, e$, which is in units of income, and can therefore be thought of as an income-equivalent of the CEO's utility. The *z* merely acts to transfer income between the Government and the Board, for example to make sure that the CEO gets enough utility to make it worth his while to participate in this activity. The interests of all principals are best served by choosing *e* to maximize the sum of the principals' benefit and the CEO's equivalent income, or the *total surplus*, $b'\, e - \frac{1}{2}\, e'\, C\, e$. The first-order condition for the maximization is $b = C\, e$, yielding $e = \Gamma\, b$. (3)

II-B. SECOND-BEST WITH THE GOVERNMENT AND THE BOARD BEING UNITED

Now suppose the effort cannot be observed, and incentive schemes for the CEO must be conditioned on the observable outcome *x*. I will restrict attention to a linear reward scheme. Holmström and Milgrom (1987) have shown that this is without loss of generality if the quadratic payoffs arise in a reduced form of a continuous-time dynamic model where the error ε cumulates as a Brownian motion. Even otherwise, linear schemes can be justified as approximations or on grounds of simplicity; they go naturally with quadratic payoffs; and are similarly used in Holmstrtöm and Milgrom (1988, 1990, and 1991) without formally specifying an underlying continuous-time dynamic model. We shall proceed on a similar basis.

We continue to suppose that all the Government and the Board act together as a benevolent dictator and work closely such as cases in strict form of public-private-partnership. Of course they remain constrained by the unobservability of effort. Suppose they contract to pay the CEO $\alpha + \beta' x$ when the outcome is x. The CEO's expected utility from making effort e is $-exp\{-r(\alpha + \beta' x - ½\ e'C\ e)\} = -exp\{-r\beta' e + ½ r^2 \beta'\Omega\beta - r\alpha + ½ r e' Ce\}$, using the standard formula for the expectation of the exponential (moment generating function) of a normally distributed variable. This can be written as $exp(-ry)$ where we got: $y = \alpha + \beta' x - ½\ r\ \beta'\Omega\beta - ½\ e' Ce$.

This much sure income will give the CEO the same utility as the actual uncertain prospect, and it can therefore be thought of as the CEO's certainty-equivalent income. The CEO's decision then consists of maximizing this certainty-equivalent income. The first-order condition for that is

$\beta - Ce = 0$, or $e = \Gamma\beta$. (4)

Remember that diagonal terms in Γ are positive, while its off-diagonal terms are generally negative. Therefore an increase in one component of β will increase that component of the CEO's effort and generally decrease the other components. Substituting for the CEO's effort, his certainty-equivalent income becomes

$y = \beta'\Gamma\beta + \alpha - ½\beta'\Gamma\beta - ½ r\beta'\Omega\beta = ½\beta'\Gamma\beta - ½ r\beta'\Omega\beta + \alpha$ (5)

and the unified Government and Board's expected income is

$E[b'x - \beta' x - \alpha] = (b - \beta)' e - \alpha = (b - \beta)'\Gamma\beta - \alpha.$ (6)

The unified principals' optimal policy is to choose β to maximize the sum of (5) and (6), or the joint surplus $(b - \beta)'\Gamma\beta + ½\beta'\Gamma\beta - ½ r\beta'\Omega\beta = b'\Gamma\beta - ½\beta'(\Gamma + r\Omega)\beta$, and choose α to transfer enough to the CEO to meet his participation constraint. The first-order condition for β is $\Gamma b - (\Gamma + r\Omega)\beta = 0$ or, multiplying by C, $b = (I + rC\Omega)\beta$, (7)

where I is the m-dimensional identity matrix.

II-C. THIRD-BEST WITH THE GOVERNMENT AND THE BOARD BEING SEPARATED

Here the Government and the Board do not act cooperatively. Each chooses an incentive scheme, the CEO responds to the whole set of incentives he faces, and we look for the Nash equilibrium of the principals' choices. CEO's effort remains unobservable, so each principal's scheme must be based on the observable outcome x. In the present context of the game between multiprincipals, there is an added point. With quadratic payoffs, when all other principals are using linear schemes, CEO's best response can be achieved using a linear scheme without further loss of generality. Thus there is an equilibrium in which linear strategies are used. However, there may be other equilibriums involving more complex schemes, which I do not consider. Holmström and Milgrom (1988) do likewise in their two-dimensional common agency model.

Denote principal j's linear schemes by $\alpha^j + \beta^{j'} x$, and let $\alpha + \beta' x$ be the aggregate of these scheme. The CEO's choice is as in the second-best, namely, $e = \Gamma\beta$, and his certainty-equivalent income is again given by (5). But now we must examine separately the relationship between each principal and the CEO. For this, we have to ask what difference it makes when the CEO deals with the j-th principal. For this, let us define the parameters of the incentives schemes aggregated over all the CEOs except j,

$A^j = \sum_{k \neq j} \alpha^k, \quad B^j = \sum_{k \neq j} \beta^k,$

If principal j did not exist, the CEO would choose $e = \Gamma B^j$. His resulting certainty-equivalent income can be calculated as in (5), and it equals $½\ B^{j'}(\Gamma - r\Omega)\ B^j + A^j$. Including principal j, the CEO's certainty-equivalent income is given by (5). Recognizing that $\alpha = A^j + \alpha^j$ and $\beta = B^j + \beta^j$, we can write this as: $½\ (B^j + \beta^j)'(\Gamma - r\Omega)(B^j + \beta^j) + A^j + \alpha^j$. Therefore the addition to the CEO's surplus that arises from his relationship with principal j is $B^{j'}(\Gamma - r\Omega)\beta^j + ½\ \beta^{j'}(\Gamma - r\Omega)\beta^j + \alpha^j$.

Principal j's expected surplus is $b^{j'} e - \beta^{j'} e - \alpha^j = (b^j - \beta^j)'\ \Gamma(B^j + \beta^j) - \alpha^j$. His surplus in the absence of the relationship with the CEO would have been $b^{j'}\Gamma B^j$, so the difference, $b^{j'}\Gamma\beta^j - \beta^{j'}\Gamma\beta^j - B^j\Gamma\beta^j - \alpha^j$, is attributable to the relationship. Once again, the β^j merely serves to transfer the surplus between the parties, and principal j will optimally choose β^j to maximize the total bilateral surplus

$b^{j\,'}\Gamma\beta^{j}$ - r $B^{j\,'}\Omega\ \beta^{j}$ - ½ $\beta^{j\,'}(\Gamma+\ r\Omega)\ \beta^{j}$. (8)

Principal *j,* who is acting noncooperatively with respect to the other principals, will make this choice of β^{j} treating B^{j} as given. The first-order condition is $\Gamma b^{j\,'} - r\,\Omega B^{j\,'} - (\Gamma+\ r\Omega)\ \beta^{j} = 0$, or, multiplying by *C,* we got $b^{j} = (I + r\,C\,\Omega)\,\beta^{j} + r\,C\,\Omega B^{j}$ (9)

This implicitly defines β^{j} given B^{j}; in other words, it is principal *j*'s best response to the choices of the other principals. In the Nash equilibrium, such relationships must hold simultaneously for all *j.* Adding them over and recognizing that $B^{j} = \beta - \beta^{j}$ sum to $(n - 1)\ \beta$ where *n* is the number of principals involved, we have $b = (I + n\,r\,C\,\Omega)\,\beta$ (10)

Let's compare the second-best incentive scheme defined by (7), where all the principals are united, and the aggregate scheme (10) emerging from the Nash equilibrium, where they are not in the much real world. The two expressions are remarkably alike, except for the factor *n* that multiplies a term on the right-hand side. In other words, the effect of the lack of cooperation between the Government and the Board is exactly as if the risk-aversion of the CEO were multiplied by a factor equal to the number of principals. Recall that the need for risk-sharing is what leads to a lower-powered scheme in the second-best as compared to the first-best. Therefore in the present "third-best" Nash equilibrium between the competing principals, the overall incentives are even less powerful than those in the second-best. Moreover, the effect is proportional to the number of principals and therefore can be quite dramatic when several of these are involved. Roughly speaking, we can say that the power of the incentive scheme becomes inversely proportional to the number of principals.

To understand the reason for this dampening of incentives, let us find an explicit expression for the equilibrium incentive scheme of an individual principal. Noting that (9) can be written as $b^{j} = \beta^{j} + r\,C\,\Omega\beta$ and substituting from (10), we find $\beta^{j} = b^{j} - r\,C\,\Omega(I + n\,r\,C\,\Omega)^{-1}\,b.$ (11)

Consider the case where $n = m$, and principal *j* has direct concern only for the output of task *j.* Then all components of b^{j} except the *j*-th are zero, but that does not hold for β^{j} . The second term in (11) contributes to all the other components of β^{j} . In the normal case, we expect all these other components to be negative. In other words, principal *j* will typically penalize all other dimensions of the CEO's effort. Of course this taken by itself lowers the CEO's utility, but the constant term α^{j} in the scheme can always be adjusted to ensure that the CEO gets non-negative surplus from his relationship with principal *j* and therefore remains willing to participate.

The point is that even though principal *j* is not directly concerned with any other components of output, he would like the CEO to exert less effort in those dimensions because that will induce the CEO to make more effort in the dimension that benefits principal *j.* This effect actually comes about through two avenues, which we see from a closer examination of the expression (8) for the bilateral surplus between the CEO and principal *j*.

The first effect comes from the second term in this expression. For simplicity, suppose that only the *j*-th component of b^{j} in principal *j*'s benefit is nonzero. (So long as the principals' interests are not perfectly aligned, that is, the vectors b^{j} are linearly independent, we can make this true by a change of the coordinate system.) Then the term is: $b^{j}_{j}\ \Sigma_{i}\ \Gamma_{j\,i}\ \beta^{j}_{i}$. When the CEO's efforts on behalf of principals *i* and *j* are substitutes in the appropriate sense, $\Gamma_{j\,i} < 0$, so principal *j* benefits from making β^{j}_{i} negative. This is an obvious direct effect. Another effect, less obvious and indirect, comes from the third term in the expression (8). The other principals' schemes B^{j} affect principal *j's* marginal choice through the risk-premium term, $-\,r\,B^{j\,'}\,\Omega\,\beta^{j}$. Because the matrix Ω has been assumed to be diagonal, this is simply: $-\,r\ \Sigma_{i} B^{j}_{i}\,\Omega_{j\,i}\,\beta^{j}_{i}$.

Let us ask if a situation where each principal chooses a scheme based only on his dimension of output can be an equilibrium. Suppose for a moment that each principal $i \neq j$ offers a positive incentive for the CEO's effort in dimension *i* and zero incentive for other dimensions. This implies $B^{j}_{j} = 0$, and $B^{j}_{i} > 0$ for all $i \neq j$ (remember that the B^{j} are the vectors of coefficients summed over all the principals *except j*). Now look at principal *j*'s best response. In the above sum, all the coefficients of β^{j}_{i} for $i \neq j$ are negative, so principal *j* benefits by making his own β^{j}_{i} negative. The reason is that these negative components induce the CEO to work less hard for the other principals, which makes his income from them less risky. Then principal *j* need only pay a smaller risk premium to induce the CEO to work harder at the margin on his own behalf. The same argument applies to all the principals, so the initial supposition of independence of their incentive schemes $(B^j_j = 0)$ cannot remain true in equilibrium. This effect persists even when the marginal cost of the CEO's effort for one principal is independent of that for others, because even when C is diagonal and therefore so is its inverse Γ. We then have: $e_i = \Gamma_{ii} \sum_j \beta^j_i$.

Of course when the CEO's cost of effort is not separable, the matrix Γ has off-diagonal terms and the other principals' interests affect the bilateral surplus through the more direct effect that was discussed earlier. Such conditioning of each principal's incentives on the outcomes of direct interest to the other principals has repercussions for the Nash equilibrium. If principal *j* increases the *j*-th component of his β^j, the CEO will increase e_j, the *j*-th component of effort. This raises the expected value of the *j*-th component of output, and therefore the CEO's receipt from principal *j*. But the other principals *k* have negative *j*-th coefficients of their incentive parameters β^k, so the CEO's payment to them increases as well. In other words, some of Government's money passes to the Board via the CEO, and vice versa. This leakage is not complete, because as (9) shows, the reaction functions do not have slope *-1*; but it is significant. For principal *j,* the leakage to other principals makes it much less desirable to offer a powerful incentive scheme. That is why the equilibrium ends up with substantially lower-powered aggregate incentives.

II-D. EFFECT OF INSTITUTIONAL RESTRICTIONS ON PRINCIPALS

If the Government and the Board could get together and make a binding agreement to offer a jointly agreed-upon incentive scheme and divide up the proceeds with suitable transfer payments among themselves, they could achieve the second-best. However, the necessary ongoing cooperation may not be possible in the infrastructure delivery's political context, and the Government or the Board each has an incentive to cheat on the agreement and offer a scheme that gets him some extra benefit. In such a situation, a constitutional provision that limits such cheating, if enforceable, can be mutually beneficial. We have seen that the problem is each principal's provision of a negative marginal incentive for the CEO's effort on behalf of the other principals. Therefore it may be desirable to have a constitutional rule that prevents such actions. This can be done either by restricting observation so that the Government and the Board cannot see the dimensions of the outcome that pertain to the other, or by forbidding effort based on such other dimensions even when they are observable. Let us examine the consequences of this.

For this, consider the case where now $n = m,$ and each principal *j* benefits from only the *j*-th component of output, so $b^k_j = 0$ for all $k \neq j$. We also restrict every vector β_j have zero coefficients β^k_j for all $k \neq j$. Then the expression (8) for the bilateral surplus between the *j*-th principal and the CEO becomes

$$b^{j\,\prime}\, \Gamma B^j + b^j_j\ \Gamma_{jj}\, \beta^j - ½\, (\Gamma_{jj} + \mathrm{r}\, \Omega_{jj})\, (\beta^j_j)^2. \tag{12}$$

Choosing β^j_j to maximize this gives the first-order condition

$$\Gamma_{jj}\, b^j_j = (\Gamma_{jj} + r\, \Omega_{jj})\, \beta^j_j\, . \tag{13}$$

The Nash equilibrium of the principals' interaction with their constrained choices is defined by these equations for all *j*. Note that the number of principals no longer multiplies the agent's risk-aversion; thus that major source of weakness of incentives is missing. In fact, the incentives in this equilibrium can be more powerful than those in the second-best. The reason is that the Government or the Board each must now use a positive coefficient on the component of output that is of direct concern to him in order to divert the CEO from tasks that benefit the other. This competition among the Government and the Board leads them to raise those coefficients to higher levels.

The effect on infrastructure delivery is seen most dramatically in the limiting case where the different components of CEO's effort become perfect substitutes in the CEO's utility function. Then the determinant of C goes to zero, and all entries in the inverse matrix Γ go to infinity. Using this in (13) above, we have $\beta^j_j = b^j_j$ for all *j*, or $\beta = b$.

The resulting aggregate incentive scheme reproduces the first-best! More generally, if different components of the effort are close substitutes, then the constrained Nash equilibrium is better than the second-best. Therefore, instead of uniting the Government and the Board, society as a whole does better to force each to compete fiercely using positive incentive for matters of direct concern to him, but prohibit them from competing by using negative incentives for matters of concern to others.

III. CONTRACT FORMS DESIGNATION

As most incentive contracts in the project sample are linear, attention is put onto this class (Holmström and Milgrom, 1987, provide a theoretical justification for the use of linear contracts). Within this class, it is simple to formalize the notion of high and low powered incentives. Suppose that the CEO's incentive (monetary or non-monetary) is of the basic form $\alpha + \beta x$ as described in last section, where x is output, β is a variable incentive depending on the performance, and α is a fixed incentive (a wage or a medal). If we compare two contracts that have the same expected value, the one with a higher β and lower α is higher powered. Indeed, when β is zero the CEO is completely insured, whereas when α is zero and β is piece-rate net of effort input cost, the transaction occurs in a market and the CEO is one of the residual claimants. The principal prediction of the model is that a high degree of complementarity, whether systematic (high cross-price elasticity of demand), random (high covariance of shocks), or in the cost of effort function (low effort substitutability), should be associated with low powered incentives. These contracts, which range from fully insurance to arms length transactions in a market, are described in turn.

- **Fully Insured Incentive (Type 1).** Under this arrangement, the CEO, who owns no assets (even no stock option), is worked as a fixed-salary employee. The contractual arrangements involve none of incentive based pay and CEOs asset ownership. Moreover, remuneration is independent of his/her effort and output.
- **Mixed (Fixed-and-Variable) Incentives (Type 2).** CEOs receive a fixed payment, which is independent of effort, and a performance-based-style payment per unit of infrastructure service consumption. Service consumption is known as the prime. The secondary activities, in contrast, consist of all other operations mostly an estate development.
- **Performance-Based Incentives (Type 3).** The remuneration for these CEOs is fully dependent on their performance. The contractual arrangements involve full degree of incentive/performance based pay. As with type two incentives, CEOs are entrepreneurs in the franchise operation and own the associated stock-option contracts. Whereas the franchise fee is, in principle, common to all franchise; fees are project specific and reflect locational advantages (especially in transit infrastructures), demand, and other service characteristics.
- **Self-Insured Incentive (Type 4).** Finally, a few franchises are privately owned by the CEO (or she owns majority of stocks). No matter the performance is good or not, he/she reserves full or majority outcomes. Whereas this arrangement is very common in some locals, it is much rare in large-scale regional infrastructure services. Self-employed CEOs, who are residual claimants with respect to all aspects of their business, own all/most-of the infrastructure assets. Nevertheless, they often pay a franchise fee or receive a small subsidy. When the government provides the franchise with some financing, the operator might amortize her loan by means of installments of franchise fee.

IV. CONTRACT CHOICE AND EMPIRICAL EXPLORATION

Comparative statics from the theoretical model form the basis of empirical test. As linear contracts are mostly used in our project sample, attention is limited to such arrangements. In this section, we assess how variations in the parameters for one task affect the choice of contract for another. Important parameters are the covariation in uncertainty across tasks, the cross price elasticity of demand, and the substitution between tasks. The contracts data pertain to information were obtained from projects of major international BOT transport infrastructure concessions awarded from late 1980s to 1990s. These awards are group by countries via income level. There are 62 effective sample points from private franchises and 58 from government agencies. To make the comparison on the same basis, we use 58 projects for econometric modelling and parameter estimation. The value of dummy variables is mainly adopted from questionnaires and interviews.

The econometric model of contract choice is a Probit equation. The dependent variable is a dichotomous indicator that equals one if the incentive is performance-based (contract type three) and zero if incentive is mixed (contract type two). The method used to assess exogeneity of regressors in Probit models is due to Rivers and Vuong (1988). It consists of adding an auxiliary equation that relates the potentially endogenous variable, w, to relevant exogenous variables, Z. The system of equations is:

$$y^* = \rho\, w + \delta' X + u\,, \tag{14}$$

$$w = \eta' Z + v \tag{15}$$

where y* is an unobserved latent variable, X is a matrix of exogenous variables, and ρ, δ, and η are parameters to be estimated. To test the exogeneity of w, the Probit MLE is applied to (14) with the OLS residuals, $\hat{v}$, from (15) as an additional regressor. The '*t-statistic*' that tests if the coefficient of $\hat{v}$ is zero involves the correlation between the OLS residual, $\hat{v}$, and the generalized residuals, $\tilde{u}$, from the Probit.

Table 1 shows summary statistics for the explanatory variables. The first row, which is for the entire sample, is followed by statistics for each country group. This table shows that an average project is serving about five thousand populations per square mile, stays operating for twenty one hours a day, and expects to produce just under thirty million passenger-trips a year. Twenty one percent have residential real-estate development activities, forty percent of the projects have commercial real-estate development ones, and ten percent have industrial real-estate development ones. Moreover, sixty six percent are government regulated, seventeen percent have both government regulation and subsidization, and the remainder or seventeen percent are government subsidized only.

Table 1 Summary Statistics – Project Characteristics

	Number of Projects	DENST (Thou. Pop. Per Mile^2)	Average HOURS (per day)	Average VOL (10^6 per year)	RREAL (% of projects)	CREAL (% of projects)	IREAL (% of projects)	REGU (% of projects)	RESUB (% of projects)
Sample	58	5.1	20.8	27.4	21	40	10	66	17
Country 1	23	5.5	21.3	29.3	20	39	4	65	22
Country 2	20	5.1	20.4	28.2	13	30	16	60	10
Country 3	15	4.7	21.2	21.5	33	53	13	73	20

Note: DENST: service density; RREAL, residential real estate developments; CREAL, commercial real estate development; IREAL, industrial real estate development; REGU, government-regulated; RESUB, with both government regulation and subsidization; country group 1 are countries with high-income at World Bank's definition; country group 2 with upper-middle-income and middle-income; and country group 3 with lower-middle income and low-income. The dummy variables equal one if the project has the corresponding characteristic and zero otherwise.

If one computes averages of TYPE across groups of projects with different characteristics, this variable can be used to compare single and multiple task projects. The first column in Table 2 indicates that there are seventeen projects offering prime transport infrastructure service only. The average of TYPE for these projects is 2.06. Columns two, three, and four pertain to group of multitask operations. Twelve have residential real estate development, twenty three projects have commercial real estate developments, and six industrial real estate development. The first and third of these groups are mutually exclusive but there is some overlap between the second group and each of the other two. Finally, TYPE averages 2.92 for the projects that have residential real estate development, 1.80 for those that have commercial real estate development, and 2.10 for those with industrial real estate development. These numbers indicate that when a second activity is added, on average, transport-service-based incentives increase significantly when this activity is a residential real estate development, fall when it is a commercial real estate development, and remain almost the same when it is an industrial real estate development. The empirical regularities therefore support one of the theoretical predictions that, to encourage less efforts allocated to primary transport service, board of directors promote higher incentives on less complementary outputs (here, the residential real estate development) than the others.

Table 2 Single and Multitask Projects Compared – Average of Contract-Type (Board's View)

	Infrastructure Services Only	RREAL	CREAL	IREAL
Average Type	2.06	2.92**	1.80	2.10
Number of Projects	17	12	23	6

Note: ** denotes difference from 2.06 at the 99% level of confidence; see Table 1 for key to abbreviations.

Table 3 indicates that from incentive regulation's view, average TYPE for transport service is 2.57. It is 2.28 for the projects that have residential real estate development, 2.71 for those have commercial real estate development, and 2.54 for those with industrial real estate development. These numbers indicate that when a second activity is added, on average, transport-service-based incentives increase significantly when this activity is a commercial real estate development, fall when a residential real estate development, and remain much the same when an industrial real estate development. The empirical regularities therefore support one theoretical predictions to incentive regulation that, to encourage more efforts allocated to primary transport service, government promote lower incentive on less complementary outputs (here, the residential real estate development) than the others.

Table 3 Single and Multitask Projects Compared – Average of Contract-Type (Government's View)

	Infrastructure Services Only	RREAL	CREAL	IREAL
Average Type	2.57	2.28**	2.71	2.54
Number of Projects	17	13	25	7

Note: ** denotes difference from 2.57 at the 99% level of confidence; see Table 1 for key to abbreviations.

The two modes of monitoring are compared in Table 4, which shows that no unified monitoring project has residential real estate developments or both government regulation and subsidization. Moreover, project concessions, which are having shorter concession period, are more likely to have commercial real estate development and being put on government regulation. Finally, all these differences are statistically significant. Tables 5 and 7 show estimated coefficients from the Probit model of contract choice; *t statistics* can be found under their respective coefficients. Equation one includes the four self-insured projects whereas equation two excludes them. Given that estimated coefficients are virtually identical in the two equations, this choice seems unimportant. Indeed, to avoid the problem of double marginalization, all subsequent equations two, three, four and five exclude the type four projects. Equation three does not contain the fixed effects, which are insignificant in equations one and two. Again, we find that coefficient estimates are insensitive to this exclusion. The implication is that there is no systematic differences, in the rules that determine, contract choice across projects.

Table 4 Averages of Characteristics of Monitoring and Contract Projects
(Mann-Whitney-Wilcoxin Test for Difference in Mean)

Type	Projects	DENST	HOURS (per day)	VOL (10^6 Units per year)	RREAL (%)	CREAL (%)	IREAL (%)	REGU (%)	RESUB (%)	DUR (years)
Unified	5	5.1	22.4	24.4	0.0**	80.0**	20.0	71.0*	0.0**	21.2**
Separated	53	5.3	20.9	30.1	40.2	24.1	8.2	68.4	21.0	28.4

Note: * denotes significance difference at the 95% level of confidence; ** denotes significance difference at the 99% level of confidence; see Table 1 for key to abbreviations.

Table 5 Probit Equations for Contract Choice (Board's View, Performance Based Incentive =1)

Equ.	DENST	HOURS	VOL	RREAL	CREAL	IREAL	REGU	RESUB	Con 1	Con 2	VHAT	DUR	CONS	N	NSI	LF (d.f.)
1	0.02	-0.19	0.75	2.64	-2.71	-0.97	-1.61	1.04	-0.41	-0.06			2.76	53	0.74	50**
	(0.9)	(-1.8)	(0.2)	(3.4)**	(-2.6)*	(-1.1)	(-2.5)*	(1.4)	(-0.5)	(-0.1)			(1.3)			(10)
2	0.02	-0.19	0.81	2.62	-2.70	-0.95	-1.61	1.04	-0.42	-0.08			2.66	50	0.72	46**
	(0.8)	(-1.7)	(0.2)	(3.4)**	(-2.5)*	(-1.0)	(-2.5)*	(1.4)	(-0.6)	(-0.1)			(1.2)			(10)
3	0.02	-0.19	0.65	2.63	-2.71	-0.86	-1.61	1.01					2.71	50	0.71	46**
	(0.9)	(-1.7)	(0.2)	(3.6)**	(-2.6)*	(-1.0)	(-2.5)**	(1.4)					(1.3)			(8)
4	0.02	-0.16	3.09	2.41	-2.46	-0.85	-1.73	1.18			0.01		3.08	50	0.71	46**
	(0.9)	(-1.0)	(0.5)	(2.8)**	(-2.2)*	(-1.1)	(-2.6)**	(1.5)			(0.5)		(1.3)			(9)
5	0.04	-0.33	2.03	3.94	-1.85	-0.07	-1.75	0.89				-0.08	3.64	50	0.80	51**
	(0.8)	(-1.7)	(0.5)	(2.5)**	(-2.0)*	(-0.4)	(-1.4)*	(0.9)				(-1.2)	(1.3)			(9)

Note: * denotes significance difference at the 95% level of confidence; ** denotes significance difference at the 99% level of confidence; Equ.: equations; Con 1: country group 1; Con 2: country group 2; CONS: constant term; N: number of observations; d.f.: degree of freedom; LF: likelihood function; VHAT: the residuals from the OLS equation for volume: NSI, Normalized Success Index; for remaining abbreviations see Table 1.

Table 6 Auxiliary Equation for Service Consumption (Board's View)

DENST	HOURS	RREAL	CREAL	IREAL	REGU	RESUB	Con 1	Con 2	CONS	N	X^2	LF (d.f.)
1.29	0.13	-0.35	-0.74	0.39	-0.22	0.51	0.93	0.86	0.41	50	0.48	54**
(2.1)*	(3.2)	(-3.4)**	(-2.8)**	(1.4)	(-0.8)	(2.1)*	(3.9)**	(3.4)**	(0.5)			(9)

Note: * denotes significance difference at the 95% level of confidence; ** denotes significance difference at the 99% level of confidence; for remaining abbreviations see Tables 1 and 5.

Table 7 Probit Equations for Contract Choice (Government's View, Performance Based Incentive =1)

Equ.	DENST	HOURS	VOL	RREAL	CREAL	IREAL	REGU	RESUB	Con 1	Con 2	VHAT	DUR	CONS	N	NSI	LF (d.f.)
6	0.01	-0.13	0.54	-2.12	2.87	-0.79	1.42	1.01	-0.35	-0.08			2.43	50	0.62	49**
	(0.7)	(-1.5)	(0.2)	(-2.9)**	(2.5)*	(-1.0)	(2.3)*	(2.1)*	(-0.4)	(-0.1)			(1.1)			(10)
7	0.01	-0.13	0.58	-2.22	-2.54	-0.75	-1.52	0.94					2.51	50	0.61	47**
	(0.8)	(-1.4)	(0.1)	(3.1)**	(-2.2)*	(-1.1)	(-2.3)**	(1.2)					(1.2)			(8)
8	0.01	-0.13	2.01	-1.93	2.93	-0.81	1.52	1.11			0.01		2.81	50	0.61	45**
	(0.7)	(-1.0)	(0.3)	(-2.8)**	(2.3)*	(-1.1)	(2.4)**	(2.3)*			(0.3)		(1.2)			(9)
9	0.02	-0.24	1.56	-2.91	1.92	-0.09	1.54	0.93				-0.05	2.93	50	0.65	48**
	(0.7)	(-1.4)	(0.4)	(-2.4)**	(2.1)*	(-0.3)	(1.9)*	(2.0)*				(-0.9)	(1.3)			(9)

Note: * denotes significance difference at the 95% level of confidence; ** denotes significance difference at the 99% level of confidence; for remaining abbreviations see Tables 1 and 5.

The auxiliary equation for transport service volume from Board's view can be found in Table 6. Identifying instruments in this regression are the project fixed effects. These effects, as well as many of the other explanatory variables, are significant. Indeed, volume is higher at projects in the highly-density service area that stay open for long hours, have neither residential nor commercial real estate development and have both government regulation and subsidization.

Equation four in Table 5 includes the OLS residuals $\hat{v}$ from the auxiliary volume equation. The associated "*t statistic*" indicates that simultaneity is not a problem. The normalized-success ratio indicates the proportion of successful predictions. The first four ratios show that predicted and observed choices coincide for approximately seventy-two percent of the projects. The likelihood ratio statistic tests the overall significance of each equation; it compares the estimated equation to one with a constant term only. All equations perform well on both counts. The final equation in Table 5 contains a concession duration variable. Duration is included as in explanatory variable to test the hypothesis that all results can be explained by correlation with an omitted variable. Indeed, longer projects seemly tend to have government regulation, have residential real estate developments, consume lower service volumes, and stay open for shorter hours. They also tend to be awarded under type three or four contracts. Table 5, however, shows that concession duration is not a significant determinant of contract choice.

Equation six in Table 7 includes all projects whereas equation seven does not contain the fixed effects from country group. Equations eight and nine test the impacts from the OLS residuals and concession duration, respectively. The associated *t statistic* indicates that simultaneity is not a problem, too. In Table 7, the first two normalized success ratios show that the predicted and observed choices approximately approach sixty-four percent of the projects. Again, the likelihood ratio statistic tests show all equation six, seven, and eight perform well on statistical significance and prediction success. The estimated equations show that performance-based incentive regulation contracts are more apt to have commercial real estate developments than mixed incentives. In addition, they are less apt to have residential real estate development.

To interpret these incentive regularities, recall that from incentive regulation's perspective the multitask model predicts that higher powered transport-service-quality incentives will be offered at projects that provide commercial real estate development compared with those that have residential real estate development. Given that the incentive for transport service consumption is higher in type three contracts, the findings concerning non-transport-service offerings again are compatible with the theory even from incentive regulation's view.

V. SUMMARY AND CONCLUSIONS

The multitask-common agency model of organizational form explains how interrelations among tasks and principals determine optimal-contractual arrangements on incentive. The outcome could be simplifies as: the equilibrium with n principals is exactly as if there is just one hypothetical principal with an objective function that is the sum of all the separate principals' objectives, but the agent's risk aversion is multiplied n-fold. Thus, the Nash equilibrium incentive scheme with n principals has, roughly speaking, only ($1/n$)-th the power of the second-best scheme that would be offered by one truly unified principal.

To do better than the Nash equilibrium, one would have to allow some explicit cooperation among the multiple principals. This may not be feasible in the context of franchised infrastructure's day-to-day interaction; but we may be able to think of some improvements. One such device would restrict each principal to basing his incentive scheme only on the dimension of the CEO's effort that is of primary concern to that principal, and would prohibit any attempts to penalize the CEO for efforts in other dimensions. In this study, this means that the Board cannot condition his payment to the CEO on the output of quality-producing nor the Government on that of profit-making. This could be done by preventing each from observing the other's outcome, or forbidding each to act on any such observation. And, each principal, in order to attempt to induce the CEO to put more effort into task that concerns him (principal), offers a higher-powered incentive scheme. In the resulting equilibrium, the overall incentives scheme is actually higher power than the one that would be offered by a single unified principal who aggregates the interest of the Board and the Government.

The most important predictions of the theoretical model are as follows. First, when transport service consumers view the output of tasks as complementary, CEOs should be given lower-powered incentives from the Board and higher-powered incentives from the Government. Indeed, the increased effort that accompanies a high incentive shifts out demand and results in a higher infrastructure rate/fare. When activities are complementary, implying that cross price effects are large, the higher transport service rate/fare dampens secondary revenues. For government, to encourage efforts allocated to primary transport service, less complementary second activity should be discouraged. Second, when uncertainty across tasks is highly correlated, CEOs should also be given lower powered incentives. Indeed, a positive relationship increases the CEO's risk and therefore her need for insurance. A negative relationship, in contrast, is a source of risk diversification.

With respect to the empirical application, the above general predictions translate into the following. For projects that are operated under separated monitoring, from Board's perspective, incentives should be higher powered if the second activity is a residential real estate development and not a commercial real estate development. This is true because transport-service and commercial real estate development is more complementary. Moreover, when one contrasts single and multiple task projects, it is likely that incentive for transport service will be higher if the second activity is a residential real estate development but not if it is a commercial real estate development. However, incentive regulation should be lower powered if the second activity is a residential real estate development and not a commercial real estate development. This is true because transport-service and residential real estate development is less complementary. And, when one contrasts single and multiple task projects, it is likely that incentive regulation for transport service will be lower if the second activity is a residential real estate development but not if it is a commercial real estate development. All of these predictions are confirmed by the data.

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計畫成果自評

本研究運用代理理論，探討最適激勵契約的研擬，以誘導高階經營團隊能改善其運輸建設生產之經管策略暨資訊對稱性，從而裨益於運輸服務提供之社會經濟效益；研究達成之目標簡述如后。

(1) 以經濟分析論證政商關係模式下，獎掖高階經營團隊生產開發型運輸建設之適當性；

(2) 以代理理論之觀點剖析高階經營團隊監管機制之問題，建立整合共同代理(Common Agency)與多項任務代理(Multitask Agency)之比較靜態理論模式，並試就不同產品替代性之探討，以確認政府與特許機構董事會對激勵契約研擬之差異;

(3) 在上述之理論模式基礎下，實證分析在具道德危機情境中，政府及董事會應如何設計經管團隊之激勵契約，以促使高階經營團隊勉力代行運輸建設生產與經營管理目標之達成。

本研究基於資料蒐集之限制僅能及於橫斷面分析，致未能進行動態模式之實證討論；此將與激勵契約之重複賽局實際情形不符，因而對於有聲譽重建之高階經營團隊激勵設計，並無法進行詳盡解釋。另外，本研究亦未對特許廠商的市場獨占策略行為提出其對激勵設計的影響，而在所蒐集之運輸建設計畫亦因資料樣本數受限，僅能及於主要地面運輸建設，未能涵括橋樑、港口及機場等運輸設施，並加以依不同運具分別進行計量經濟模型分析。惟本研究所建立之理論模型及實證分析架構，已能處理運輸建設民營化的管理代理、產品特性與激勵設計之關鍵課題，將來若待運輸建設民營化之運具種類上及時間序列上的實證樣本資料能更完備，將更能完整彌補上述之研究缺憾。