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Complementarity Among Vertical Integration Decisions: Evidence from Automobile Product Development*

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Online Appendix A
A Model of Contracting Complementarity

This supplemental section develops a simple model of contracting complementarity even when the *ex ante* cost of specifying contracts is the same whether or not the system is outsourced. We link complementarity to specific features of the contracting environment, identifying the economic forces giving rise to contracting complementarity when the firm makes multiple vertical integration decisions across (interdependent) functional activities. Rather than develop a complete multilateral bargaining model, this "reduced-form" model assumes how the value of internal and external contracting depends on other aspects of the contracting environment. In so doing, we highlight the impact of multi-dimensional effort supply and trade secrecy concerns on contracting complementarity.

The Firm's Objective Function

We consider a simple production environment where the automobile producer (the "firm") must contract for the development of two automobile systems, A and B, in order to produce a new automobile model. While system-specific performance is important, overall performance also depends on the level of system-to-system coordination. Effective coordination imposes additional costs on the firm, and some of these costs depend on the chosen vertical structure. We assume that a higher level of coordination can be achieved by inducing a higher level of (non-contractible) coordination effort and/or by the disclosure of crucial model-level design details to each team. However, these benefits are traded off against a lower level of system-specific effort and an increased probability that trade secrets are publicly revealed.

Total profits depend on the performance of each system (f^A and f^B), the degree of coordination between the systems (f^I) and whether the design remains a secret ($c(\theta)$). System-specific performance is a function of the level of system-specific effort, which depends on whether the system is outsourced or not and the incentive scheme employed by the firm. For each system i, let y_i = 0 be defined as an outsourced team and y_i = 1 as in-house development. Moreover, the firm can choose to implement an explicit or subjective incentive scheme for each system. Let x_i = 0 be defined as employing explicit incentive scheme for agents responsible for system i and x_i = 1 a subjective performance evaluation scheme. Further, the firm can improve the degree of integration by disclosing design choices to both teams (d = 1; 0 else). Finally, for f^i, let Z_i be exogenous factors impacting the returns to i. This structure yields the following total profit function:

$$\Pi = f^A(x_A, y_A; Z_A) + f^B(x_B, y_B; Z_B) + f^I(x_A, x_B, y_A, y_B, d; Z_I) - c(\theta(y_A, y_B, d))$$

For each system, performance depends on the pre-existing capability level of the team chosen, the system-specific effort level, and a random component. As such, our approach differs implicitly from the theoretical literature insofar as we are assuming that one cannot acquire external teams. In other words, pre-existing system-specific sunk investments or capabilities that have historically maintained by the firm internally predispose the firm to continue in-house production.

Moreover, the system-specific effort level (e_i^{SS}) depends on the chosen incentive scheme and whether the system is outsourced or not, resulting in the following expression for system-specific performance:

$$f_i^{y_i} = h(Z_i^{y_i}) + \mathrm{e}_\mathrm{i}^{\mathrm{SS}}(x_i, y_i) + \eta_i \qquad (x_i \in \{0,1\}; y_i \in \{0,1\})$$

There will be variation across model-systems as to whether external or in-house teams have a greater pre-existing capability level (or current capacity to complete the work). Indeed, this form of variation – factors impacting system-level performance but unrelated to the interdependencies among systems – is the key to the empirical identification strategy described in Section IV.

For simplicity, we assume that the benefits from increased coordination can be separably decomposed into the benefits arising from the interaction between the incentive scheme and the outsourcing choice (f_x^I), and the benefits from a higher level of disclosure (f_d^I). The benefits to coordination, f_x^I, is sensitive to the level of coordination effort by each team (e_i^{INT}, $i = A, B$). Because effective coordination depends on interactions between the parties, we specify the net benefits from integration effort as the *product* of the coordination effort by each team:

$$f_x^I = \prod_{i=A,B} e_i^{INT}(x_i, y_i) \qquad (x_i \in \{0,1\}; y_i \in \{0,1\})$$

As well, beyond a baseline level, effective coordination depends on disclosure (d = 1), the benefits of which may depend on specific features of the product development environment (Z_d^I) but are independent of the chosen ownership structure ($f_d^I = d * Z_d^I$). However, the probability that model-level design information is disclosed to competitors , θ, increases from θ_L to θ_H when $d = 1$ and either $y_A = 0$ *or* $y_B = 0$. In other words, in the case where the integration benefit is realized, the disclosure probability depends on whether at least one of the systems is outsourced.[1] Taken together, these assumptions yield the firm's overall objective function:

$$\underset{x_A, x_B, y_A, y_B, d}{Max}\ \Pi = \sum_{i=A,B} (h(Z_i^{y_i}) + \mathrm{e}_\mathrm{i}^{\mathrm{SS}}(x_i, y_i)) + \prod_{i=A,B} e_i^{INT}(x_i, y_i) + d * Z_d^I - (d(1 - y_A y_B)(c(\theta_H) - c(\theta_L)))$$

Incentives, the Contracting Environment and Effort Supply

[1] The baseline probability of disclosure is greater than zero in order to be consistent with the idea that disclosure itself is non-contractible, as the "source" of competitive intelligence cannot be verified. As well, while the current model assumes that the potential for expropriation does not increase when *both* teams are outsourced (relative to θ_H), we can accommodate this extension as long as $c(\theta | d = 1, y_A = 0, y_B = 0) - c(\theta_H) \le c(\theta_H) - c(\theta_L)$.

Optimal contracting and incentive scheme choices are based on the relative benefits of in-house versus supplier development and how these choices interact with the potential costs of disclosure. For each development team, the firm chooses between an explicit and subjective incentive scheme. While the explicit scheme is contract-based and payoffs are contingent on observable and verifiable criteria, the subjective scheme depends on "soft" information across a wider range of dimensions (Baker, Gibbons and Murphy, 1994; 2002; Levin, 2003). We assume that explicit contract terms can only be provided for system-specific performance measures, and the ability to contract on the degree of coordination is limited by the absence of verifiable information. As mentioned earlier, even though formal contracts in the automobile industry do specify that coordination requirements, the inability to document the source of failure over a coordination issue limits the effectiveness of formal contracts for this purpose. In other words, while the *ex ante* costs of writing contract specifications is the same for in-house and external teams, *ex post* differences in the contracting environment lead to differences in the effort levels of in-house versus external teams under each incentive scheme.

Under an identical explicit incentive scheme, external teams will provide a higher equilibrium level of system-specific effort than in-house teams. This difference arises because performance is observed with a long lag, and the terms of contracting are subject to renegotiation when performance is observed.[2] Once performance is observed, external suppliers can expect to have little bargaining power, as they will likely have no ongoing contractual relationship with the firm.[3] As such, when contract specifications are not met (e.g., a verifiable system-specific failure occurs), the manufacturer can (and will) enforce whatever contractual penalties are specified. By writing an enforceable contract with severe penalties in the case of system failure, the firm can induce a high level of system-specific effort by choosing an external supplier. Auto manufacturers and their suppliers can (and do) litigate disputes through arbitration or formal litigation on a regular basis. In contrast, enforcing severe penalties against in-house product development teams is more difficult. By the time performance is observed, team members will be working on *new projects* for the firm; as a result, the threat of hold-up counter-balances the threat of penalties by the firm. The continuing involvement of the in-house teams with the firm reduces the ability of the firm to commit to explicit contract-based penalties associated with system failure.[4] As a result, even though the ex ante costs of specifying contracts is identical, the equilibrium level of system-specific effort will be lower for in-house development teams under ($e_i^{SS}(0,0) > e_i^{SS}(0,1),\ i = A, B$). Further, because coordination effort is non-contractible, employing an explicit incentive scheme limits the ability to induce effort towards coordination, and there is no

[2] More precisely, the timing associated with observing a *failure* is uncertain, as it depends on the accumulation of user evidence (e.g., consumer complaints, crash rates, etc.). The assumption is that the expected ability to renegotiate contracts differs across in-house versus external suppliers at the time of initial contracting.

[3] Typically, time between major changes is 3-5 years, and it is unlikely that the same supplier is working on a new project for the same manufacturer in the same vehicle segment at the time when failure is observed.

[4] Moreover, the ability to specify performance incentives for individual employees is limited by the fact that (a) employees are dispersed throughout the firm and so the cost of enforcing provisions may have a large impact on projects throughout the firm and (b) individual liquidity constraints constrain the ability of the firm to specify monetary damages of the type that are routinely used in supplier contracts.

difference in the level of effort devoted by an in-house or external team. For simplicity, we normalize the level of coordination effort under explicit incentives to 0 for both in-house and external teams (i.e., $e_i^{INT}(1,0) = e_i^{INT}(1,1) = 0$).

In contrast to an explicit incentive contract, a subjective incentive scheme can induce effort along both dimensions, even though coordination effort is non-contractible. More specifically, the firm can use the potential for repeated interaction to establish relational contracts inducing effort on dimensions over which managers can make (non-verifiable) inferences about the level of effort (Baker, Gibbons and Murphy, 1994; 2002; Levin, 2003). Inducing effort on non-contractible dimensions comes at the expense of high-powered incentive contracting on dimensions for which contracting is feasible; as a result, for a given team (in-house or external), the equilibrium level of system-specific effort is lower under subjective relative to explicit incentives ($e_i^{SS}(0,\ .) > e_i^{SS}(1,\ .)$). However, relative to an external team, an in-house team provides a higher level of coordination effort under subjective incentives than an external team:

$$e_i^{SS}(1,\ 0) < e_i^{SS}(1,\ 1)$$
$$e_i^{INT}(1,\ 0) < e_i^{INT}(1,\ 1)$$

Those factors limiting the ability of the firm to enforce formal contract terms against in-house employees are precisely those which allow the firm to implement relational contracting. For example, while a long-term employment relationship with the firm limits the power of formal contracts (because of the potential for hold-up), this relationship allows the firm to use subjective promotion decisions to induce effort on non-contractible dimensions. While relational contracting across firms may also be feasible (as emphasized in Baker, Gibbons and Murphy (2002)), the effectiveness of inter-firm subjective contracting is limited – relative to what is achievable for employees within the firm -- by the lower probability of a repeated relationship across firm boundaries.[5]

Finally, we also assume that the firm cannot specify specific penalties for trade secrecy violations; while an occasional instance of industrial espionage will result in a supplier being caught “red-handed,” most expropriation occurs without the firm’s knowledge and with few clues as to the precise source of the disclosure of competitive intelligence.

Optimal Contracting, Disclosure and Complementarity

The firm simultaneously chooses whether to vertically integrate each product development team, the incentive scheme to provide each team, and whether to facilitate coordination through disclosure. Interdependencies across vertical choices arise through the coordination effort decisions and through the disclosure decision.

Proposition 1: $\Pi(x_A, x_B, y_A, y_B, d)$ is supermodular in x_A, x_B, y_A, y_B, and d.

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[5] If overall effort supply is inelastic, it is possible that $e_i^{SS}(1,\ 0) > e_i^{SS}(1,\ 1)$. This does not change the overall analysis as long as subjective incentives are pairwise complements with in-house production.

Proof of Proposition 1: The proof proceeds by showing pairwise complementarity among each of the choice variables. Letting Δ_i refer to the difference in Π from shifting *i* from 0 to 1 (and Δ_{ij} is analogously the double-difference operator), we need to show that

$$\forall \text{ pairs } (i, j) \in \{x_A, x_B, y_A, y_B, d\},$$

$$\Delta_{ij} - \Delta_i - \Delta_j > 0 \quad \forall\, x_A, x_B, y_A, y_B, d$$

We begin with the pair (x_A, y_A). Since *d* does not interact with x_A, we abstract away from the level of *d*. As well, when $x_B = 0,\ f_x^I = 0 \quad \forall\, x_A, y_A, y_B$. In the case when $x_B = 0,$ we thus need only show $e_A^{SS}(1,1) + e_A^{SS}(0,0) - e_A^{SS}(1,0) - e_A^{SS}(0,1) > 0$. This follows from two observations:

$e_A^{SS}(1,1) > e_A^{SS}(1,0)$ (in-house subjective effort is higher than external subjective effort)

$e_A^{SS}(0,1) < e_A^{SS}(0,0)$ (in-house explicit effort is lower than external explicit effort).

When $x_B = 1,$ we also consider whether

$$e_B^{INT}(1,.) * (e_A^{INT}(1,1) + e_A^{INT}(0,0) - e_A^{INT}(1,0) - e_A^{INT}(0,1)) > 0.$$

Complementarity among (x_A, y_A) is ensured because $e_A^{INT}(0,0) = e_A^{INT}(0,1) = 0$, . An identical argument holds for (x_B, y_B).

We next consider (y_A, y_B). When x_A or x_B = 0 *and d* = 0, there is no interaction between (y_A, y_B). When x_A and x_B = 1 (maintaining *d* = 0) , we must determine the sign of:

$$e_A^{INT}(1,1)\, e_B^{INT}(1,1) + e_A^{INT}(1,0)\, e_B^{INT}(1,0) - e_A^{INT}(1,0)\, e_B^{INT}(1,1) - e_A^{INT}(1,1)\, e_B^{INT}(1,0).$$

This can be rewritten as:

$$e_A^{INT}(1,1)\,(e_B^{INT}(1,1) - e_B^{INT}(1,0)) - e_A^{INT}(1,0)\,(e_B^{INT}(1,1) - e_B^{INT}(1,0))$$

which can be further rewritten as:

$$(e_A^{INT}(1,1) - e_A^{INT}(1,0))\,(e_B^{INT}(1,1) - e_B^{INT}(1,0))$$

Each of these terms is positive by assumption since in-house subjective incentives induce higher effort than external subject incentives. Finally, when *d* = 1, we must also consider the term $c(\theta_H) - c(\theta_L)$, which is also positive by assumption, yielding complementarity between (y_A, y_B).

We next consider (x_A, y_B). When $x_B = 0,$ there is no interaction between these two variables. Assuming $x_B = 1,$ we can write the inequality for complementarity as:

$$e_A^{INT}(1,.)\, e_B^{INT}(1,1) + e_A^{INT}(0,.)\, e_B^{INT}(1,0) - e_A^{INT}(0,.)\, e_B^{INT}(1,1) - e_A^{INT}(1,.)\, e_B^{INT}(1,0) > 0$$

Since $e_A^{INT}(0,.) = 0$, this reduces to $e_A^{INT}(1,.)\,(e_B^{INT}(1,1) - e_B^{INT}(1,0)) > 0$ which follows from the assumption that in-house subject incentives induce higher effort than external subjective incentives. An identical argument holds for (x_B, y_A).

We now consider complementarity between (x_A, x_B), or the sign of the following:

$$e_A^{INT}(1,.)\, e_B^{INT}(1,.) + e_A^{INT}(0,.)\, e_B^{INT}(1,.) - e_A^{INT}(1,.)\, e_B^{INT}(0,.) - e_A^{INT}(0,.)\, e_B^{INT}(0,.) > 0$$

This inequality is strict because $e_A^{INT}(0,.) = e_B^{INT}(0,.) = 0,$ and $e_i^{INT}(1,.) > 0$.

The final pairwise complementarity to check is (y_A, d). The complementarity inequality for this pair reduces simply to $(1 - y_A)(c(\theta_H) - c(\theta_L)) \geq 0$ which holds by assumption about the costs of disclosure.

There are two distinct drivers of complementarity among vertical integration choices in this model. First, because coordination requires interaction (and so coordination efforts are complements) and in-house development teams are more sensitive to subjective incentive schemes that induce a positive level of coordination effort, the contracting choices for the two teams become interdependent. In other words, contracting complementarity results because the benefits of coordination are sensitive to the *least* effort provided, and the level of coordination effort is sensitive to the vertical integration choice. As well, contracting complementarity arises because of the non-contractibility of the trade secrecy clause and the fact that the probability of expropriation increases most steeply with the first instance of external contracting. Another interpretation of this second channel for contracting complementarity is that the types of investments to ensure against expropriation result in economies of scale in outsourcing; the marginal "costs" of external governance are declining in the level of external governance.

Simplifying notation so that Z_i are system-specific factors favoring vertical integration for system i, Proposition 1 implies the comparative statics motivating the empirical strategy:

Remark: $x_A^*, x_B^*, y_A^*, y_B^*$, and d^* are weakly increasing in Z_A and Z_B, and weakly decreasing in Z_D and $c(\theta_H) - c(\theta_L)$.

Proof: Since each of the exogenous variables has a monotone relationship with each of the y_i, the comparative statics with respect to Z_i and $c(\theta_H) - c(\theta_L)$ are a direct consequence of Milgrom and Shannon (1994, Proposition 4).

Online Appendix B

Pairwise Correlations

	VI	SUNK COST	LOW CAP	PLATFORM	COMPLEXITY	UNION	DESIGN GOAL	SKILL SHORTAGE
VERTICAL INTEGRATION	1.00							
SUNK COST	-.01	1.00						
LOW CAPACITY	-.25*	.30*	1.00					
PLATFORM	.07	.05	-.00	1.00				
COMPLEXITY	-.15	.02	-.11	-.13	1.00			
UNION	.55*	.22*	-.15	.17	-.31*	1.00		
DESIGN GOAL	-.13	-.14	-.17	-.10	.24*	-.23*	1.00	
SKILL SHORTAGE	-.26*	.47*	.59*	.10	-.06	-.02	-.14	1.00

Note: A star denotes statistical significance at 5% significance level.

Online Appendix C-1

BETWEEN ESTIMATORS AND INITIAL CONDITIONS ESTIMATORS
(BOTH OLS AND INSTRUMENTAL VARIABLES)
PRE-EXISTING CAPABILITIES AND RESOURCES SPECIFICATION

Dependent Variable : VERTICAL INTEGRATION				
	OLS Regressions		Instrumental Variables Regressions	
	(C1-1) Between Estimator (N=133, 49 groups)	(C1-2) Initial Conditions Estimator (N = 84)	(C1-3) Between IV Estimator (N = 133, 49 groups)	(C1-4) Initial Conditions IV Estimator (N = 84)
VERTICAL INTEGRATION$_{-i}$	.138***	.133***	.155***	.153***
	(.023)	(.022)	(.029)	(.034)
SUNK COST	.022		.011	
	(.115)		(.116)	
LOW CAPACITY	-.192**		-.180*	
	(.098)		(.099)	
SUNK COST$_0$		.017		.008
		(.072)		(.084)
LOW CAPACITY$_0$		-.217***		-.209
		(.062)		(.065)
CONSTANT	.107*	.142*	.062	.079
	(.072)	(.077)	(.087)	(.105)
R^2 Within	.016			
R^2 Between	.498			
R^2 Overall	.470	.440		
RHS Endogenous Variables			VERTICAL INTEGRATION$_{-i}$	VERTICAL INTEGRATION$_{-i}$
Instrumental Variables			For system *i* of model *j*, sum each model-specific measure for all systems but *j*: $Z_{-i,j,t} = \left(\sum_{l=1,\dots,7} Z_{ljt} - Z_{ijt} \right)$	
			$Z = \left\{ \begin{matrix} \overline{\text{SUNK COST}} \\ \overline{\text{LOW CAPACITY}} \end{matrix} \right\}$	$Z = \left\{ \begin{matrix} \text{SUNK COST}_0 \\ \text{LOW CAPACITY}_0 \end{matrix} \right\}$

Notes: (1) Stars denote 1 (***), 5 (**), and 10% (*) statistical significance level.
(2) Equation (C1-1) and (C1-3): Standard errors are unadjusted as procedure is at the model-system level.
(3) Equation (C1-2) and (C1-4): Standard errors are clustered at the model-system level.
(4) Equation (C1-2) and (C1-4): Z_0 is the initial value for the system-specific measure Z for a given model-system (Z is either SUNK COST or LOW CAPACITY). The initial observation for each model-system is dropped so that the initial conditions estimators relies exclusively on variation across models in the level of pre-existing capabilities and resources prior to the time of the first vertical integration contracting choice for that model-system.

Online Appendix C-2

BETWEEN ESTIMATORS AND INITIAL CONDITIONS ESTIMATORS
(BOTH OLS AND INSTRUMENTAL VARIABLES)
DESIGN AND MANUFACUTING CHALLENGE INDICES

Dependent Variable : VERTICAL INTEGRATION				
	OLS Regressions		Instrumental Variables Regressions	
	(C2-1) Between Estimator (N=133, 49 groups)	(C2-2) Initial Conditions Estimator (N = 84)	(C2-3) Between IV Estimator (N = 133, 49 groups)	(C2-4) Initial Conditions IV Estimator (N = 84)
VERTICAL INTEGRATION$_{-i}$	.146***	.151***	.179***	.195***
	(.024)	(.025)	(.061)	(.039)
PLATFORM	.038		.042	
	(.073)		(.075)	
COMPLEXITY	.038		.082	
	(.157)		(.177)	
PLATFORM$_0$		.089		.102
		(.078)		(.082)
COMPLEXITY$_0$		.164		.240
		(.137)		(.159)
CONSTANT	.019	-.056	-.089	-.219
	(.118)	(.108)	(.217)	(.173)
R^2 Within	.074			
R^2 Between	.456			
R^2 Overall	.447	.404		
RHS Endogenous Variables			VERTICAL INTEGRATION$_{-i}$	VERTICAL INTEGRATION$_{-i}$
Instrumental Variables			For system *i* of model *j*, sum each model-specific measure for all systems but *j*: $Z_{-i,j,t} = \left(\sum_{l=1,\dots,7} Z_{ljt} - Z_{ijt} \right)$	
			$Z = \left\{ \begin{matrix} \overline{\text{SUNK COST}} \\ \overline{\text{LOW CAPACITY}} \end{matrix} \right\}$	$Z = \left\{ \begin{matrix} \text{SUNK COST}_0 \\ \text{LOW CAPACITY}_0 \end{matrix} \right\}$

Notes: (1) Stars denote 1 (***), 5 (**), and 10% (*) statistical significance level.
(2) Equation (C2-1) and (C2-3): Standard errors are unadjusted as procedure is at the model-system level.
(3) Equation (C2-2) and (C2-4): Standard errors are clustered at the model-system level.
(4) Equation (C2-2) and (C2-4): Z_0 is the initial value for the system-specific measure Z for a given model-system (Z is either PLATFORM or COMPLEXITY). The initial observation for each model-system is dropped so that the initial conditions estimators relies exclusively on variation across models in the level of design and manufacturing challenges prior to the time of the first vertical integration contracting choice for that model-system.

Online Appendix C-3

BETWEEN ESTIMATORS AND INITIAL CONDITIONS ESTIMATORS (BOTH OLS AND INSTRUMENTAL VARIABLES) FULL SPECIFICATION

Dependent Variable : VERTICAL INTEGRATION				
	OLS Regressions		Instrumental Variables Regressions	
	(C3-1) Between Estimator (N=133, 49 groups)	(C3-2) Initial Conditions Estimator (N = 84)	(C3-3) Between IV Estimator (N = 133, 49 groups)	(C3-4) Initial Conditions IV Estimator (N = 84)
VERTICAL INTEGRATION$_{-i}$	.148***	.136***	.170***	.170***
	(.026)	(.031)	(.035)	(.033)
SUNK COST	.135		.148	
	(.120)		(.122)	
LOW CAPACITY	-.162		-.159	
	(.110)		(.111)	
PLATFORM	.025		.036	
	(.070)		(.072)	
COMPLEXITY	.063		.056	
	(.144)		(.146)	
SUNK COST$_0$		.151		.168
		(.096)		(.103)
LOW CAPACITY$_0$		-.228***		-.225***
		(.067)		(.071)
PLATFORM$_0$		-.019		.005
		(.056)		(.057)
COMPLEXITY$_0$		.187		.204
		(.166)		(.171)
UNION	.008	.065	.228*	-.010
	(.091)	(.095)	(.118)	(.105)
Parametric Restrictions	#Restr F-Stat p-value	#Restr F-Stat p-value	#Restr F-Stat p-value	#Restr F-Stat p-value
SYSTEM DUMMIES	6 5.60 0.00	6 4.67 0.00	6 33.80 0.00	6 4.82 0.00
GENERATION DUMMIES		2 0.06 0.94		2 0.04 0.96
CONSTANT	.269**	.230	-.089	.148
	(.110)	(.148)	(.217)	(.143)
R^2 Within	.021			
R^2 Between	.745			
R^2 Overall	.683	.692		
RHS Endogenous Variables			VERTICAL INTEGRATION$_{-i}$	VERTICAL INTEGRATION$_{-i}$
Instrumental Variables			For system *i* of model *j*, sum each model-specific measure for all systems but *j*: $Z_{-i,j,t} = \left(\sum_{l=1,\dots,7} Z_{ljt} - Z_{ijt} \right)$	
			$Z = \left\{ \overline{\text{SUNK COST}}, \overline{\text{LOW CAPACITY}}, \overline{\text{PLATFORM}}, \overline{\text{COMPLEXITY}} \right\}$	$Z = \left\{ \text{SUNK COST}_0, \text{LOW CAPACITY}_0, \text{PLATFORM}_0, \text{COMPLEXITY}_0 \right\}$

Notes: (1) Stars denote 1 (***), 5 (**), and 10% (*) statistical significance level.
(2) Equation (C3-1) and (C3-3): Standard errors are unadjusted as procedure is at the model-system level.
(3) Equation (C3-2) and (C3-4): Standard errors are clustered at the model-system level.
(4) Equation (C3-2) and (C3-4): Z_0 is the initial value for the system-specific measure Z for each model-system

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