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# Does Ownership Affect the Variability of the Production Process? Evidence from International Courier Services

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A firm often must ensure that products or services it produces match customer expectations. We define variability as any deviation in a production process yielding products or services whose attributes differ from the firm's stated target specifications. Firms pursuing products marked by low variability are more subject to maladaptation costs if production processes are not adjusted to avoid nonconformities. Furthermore, such adjustments often require idiosyncratic investments (e.g., dedicated information technology systems), thereby creating contractual hazards and potential underinvestment. We hypothesize that ownership of sequential activities in the value chain helps mitigate problems associated with maladaptation as well as suboptimalities in transaction-specific investment, thereby resulting in lower variability. Using data on delivery times from the Japanese international courier and small package services industry, we assess the variability-reducing role of ownership in two complementary ways. The first approach is parametric, allowing us to assess the impact of ownership on the variance associated with delivery time; here we focus on shipments that frequently fail to arrive precisely within the time period initially expected by customers. The second approach is more consistent with the notion of reliability, or the likelihood that shipments will not arrive later than expected: we nonparametrically estimate the distribution of deviations between actual and expected delivery time, and verify how distinct organizational choices change the distribution. Ownership of multiple segments yields a particularly pronounced effect on both variance and reliability. Ownership bestows variability-reducing benefits of ownership, especially when ownership is observed in multiple stages of the value chain.

*Key words:* organizational choice; contracting; governance; reliability; variance; variability

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## Introduction

For decades, management scholars have recognized the benefits of crafting production processes that lead to products or services whose attributes are aligned with the expectations of customers. Although a diverse set of products varying in attributes allows firms to target multiple customer segments, any given product should meet certain customer expectations or standards (Deming 1982; see also Tan et al. 2002, Salvador et al. 2001). Significant deviations between initial customer expectations and actual product performance—as illustrated by high product defect rates or unpredictable service delivery—are manifestations of high variability and would likely result in dampened customer satisfaction and lost customers (e.g., Deming 1982, Lee et al. 2001, Cejer 2003, Punis 1994). Yet, although scholars have advocated reducing variability through a variety of

operational practices such as concurrent engineering and statistical quality control (SQC), we know little about how to support and foster those practices with the use of appropriate *organizational* mechanisms.

Building upon transaction cost economics, we argue that organizational choices—in particular, owning sequential activities in the value chain versus outsourcing them to other parties—affect variability in two important ways. First, the goal of lower variability in production processes, associated with less tolerance to nonconformities, magnifies the significance of disturbances or external shocks that beforehand were deemed unremarkable. Because more disturbances then require attention, a more highly sensitive and larger set of responses to those disturbances, although required, would not all be resolved through contract-based outsourcing. For instance, although it is possible to establish

penalties for late delivery, it is not possible to anticipate contractually all possible external contingencies that might induce delays. Any resulting maladaptation can be avoided via fiat afforded by ownership. Second, whereas idiosyncratic assets certainly can be designed to help drive and improve average performance, they can also serve to lower variability in production processes—consider, for instance, investments in information technology (IT) to monitor and detect nonconformities. Plans to invest in such idiosyncratic assets open the door for holdups and, thus, underinvestment, both of which are avoided when activities are owned (Williamson 1985, 1991). In short, efforts to decrease variability in product attributes require superior adaptation to disturbances, as well as investment in highly specialized assets to detect nonconformities. If the benefits from reducing variability supplant the added costs to control sequential processes of a given value chain, then ownership is warranted.

We test this claim using data from the international courier and small package (IC&SP) services industry in Japan (Nickerson et al. 2001), which is a market segment where low variability in the *delivery time* of shipments is desirable and valued by customers. Instead of analyzing delivery time directly, we compute how the delivery time of each parcel deviated from what would be expected given certain parcel- and firm-specific characteristics. Thus, the product attribute we observe is delivery time, and the deviation we consider is the difference between actual and expected time. Based on this variable, we then evaluate the effect of ownership along three transportation segments of the value chain—domestic trucking, international air transportation, and foreign trucking—on deviations from expected delivery time.

We empirically assess variability in two complementary ways. The first approach employs the standard measure of *variance*: the degree of dispersion in a product or service attribute reflected by a batch of units. In our case, variance is high insofar that shipments frequently (and sometimes dramatically) fail to arrive precisely within the time period initially expected by customers. A potential criticism associated with using variance in our context is that customers may not necessarily care if a parcel arrives earlier than expected; they may be more interested in guaranteeing that no late delivery will occur. In other words, customers may set certain aspiration levels—e.g., the parcel should arrive in a certain number of days—and then assess the “downside risk” that the service will fail to meet their aspiration (e.g., Miller and Leiblein 1996). Based on this idea, we refer to *reliability* as “the probability that a component or system will perform a required function” (Ebeling 1997, p. 5; also see Garvin 1987), or, in our context, the probability that parcels will *not* arrive later than initially expected. In contrast to a single parameter such as variance, the analysis of reliability requires an observation of the overall distribution of occurrences in a particular production process. In particular, reliability-sensitive customers

likely value organizational actions that reduce the density of shipments that would otherwise arrive late—i.e., they prefer a skew in the probability distribution function of delivery time that is marked by a compression in the right-hand portion of the curve.

In this sense, we employ two distinct methods to evaluate the impact of organizational choice on variability. The first method, consistent with the variance-based operationalization of variability, parametrically evaluates the impact of ownership of value-chain activities on the variance of deviations between actual and expected delivery time. The second method, consistent with the notion of reliability, employs a nonparametric technique to estimate how the distribution of those deviations changes according to distinct patterns of ownership along the value chain. Both methods attempt to address couriers’ endogenous choice of organizational form, which may affect estimates. We find that ownership of certain transportation segments contributes to some reduction in the variance of delivery time and in the frequency of shipments that arrive after the expected delivery time. Although the latter effect is small in the case of ownership of any one singular transportation segment, it becomes more pronounced when the firm has ownership stakes in multiple segments. Thus, multiple ownership in our context appears to have a higher impact in terms of reliability than variance. The nonstandard empirical tools employed in this paper now can be used in the future to assess the effect of organizational choice on the variability of production processes crucial to a firm’s performance.

Our results contribute to both organizational economics and supply chain management, as well as strategic management more generally. First, whereas organizational economics until now has scrutinized the effects of organizational choice on average performance,<sup>1</sup> we highlight effects on the variation of product performance, indicated by the frequency at which levels of particular attributes are attained. Firms should consider the potential effects of controlling via ownership the activities that contribute to a reduction in the variability of attributes that are valued by customers. Customers may not only be interested if a product or service meets certain standards on average, but also if there is a high incidence of painful or unpredictable nonconformities that represent a mismatch between initial expectations and actual performance. Second, this paper informs the supply chain management literature by describing the mechanisms by which ownership leads to lower variance and higher reliability. According to Flynn and Flynn (2005), to better inform the management of supply chains, transaction cost analysis should not only focus on costs, but also pay attention to other relevant factors such as quality. Finally, we contribute to the strategic management literature by linking ownership to the firms’ capacity to develop a

reputation for supplying products and services that frequently meet customer expectations, thereby eventually leading to valuable product differentiation and sustainable competitive advantage.

This paper proceeds as follows. In the next section, we describe generally the efforts that firms make to pursue low-variability production processes, the contractual hazards and costs that plague these efforts, and how ownership ameliorates those hazards. Then we describe our data and the empirical methods. We discuss the results, point out limitations and future research extensions, and end with concluding remarks.

### Variability and Organizational Form

We argue below that attempts to decrease variability open the door for contractual hazards, and that hazards can be reduced by owning sequential activities along the value chain. When the reduction of those hazards is worth the additional costs of control, ownership is recommended.

#### Variability

Firms often sell a broad variety of products and services that target diverse customer segments. Offering products and services with varying attributes is a way to address heterogeneous preferences in the marketplace (Lancaster 1990). However, a firm often must ensure that products or services it actually offers match customer expectations (Deming 1982). For example, a home alarm manufacturer may guarantee that its home alarm will go off at 150 decibels over its lifetime. However, if a batch of alarms is found to sound at only 120 decibels, this would indicate a deviation of 30 decibels from the specification the firm promises its customers. We term *variability* as any deviation in a production or service delivery process that yields products or services whose attributes differ from the firm's stated target specifications.<sup>2</sup>

Variability is important in terms of performance because it dictates the degree to which customer expectations are met and sales sustained (e.g., Deming 1982, Lee et al. 2001, Cejer 2003, Punis 1994). Given a production or service delivery process, if customers discover that attributes consistently deviate from their initial expectations, they will not be pleased or satisfied (e.g., Simester et al. 2000; see also Zeithaml et al. 1993). Not only will customers likely not repeat purchases, but they will lower the firm's reputation via word of mouth (Anderson and Sullivan 1993). Of course, firms may offer warranties on products to entice purchases (Huang et al. 2007), in which case customers will return defective products for exchange or repairs in hopes for improvements. Even the choice to offer warranties, however, depends on a cost-to-benefit analysis, and, if variability of production processes unexpectedly spikes, then the cost of the warranty provision may increase dramatically and incur a financial loss for the firm.

A straightforward way to assess variability is to examine the *variance* associated with a given production process. High variance is characterized by large and unpredictable deviations between actual and expected product (or service) attributes. Returning to the example above, if a batch of home alarms includes some units that go off at an abnormally high level of decibels and others that go off at a very low level, then there is high variance in the sound-generating portion of the alarm manufacturing process. Often, manufacturers or service providers will rely on "six sigma," a quality management process that helps organizations more rigorously control activities for process improvement (Schroeder et al. 2008). Six sigma efforts usually involve the so-called "S-chart," which plots the sample standard deviation of a product attribute over time (von Collani and Sheil 1989) and can be used to control service or product quality (e.g., Gardiner and Mitra 1994).

However, in some circumstances customers may only care if attribute levels fall short of a given standard. For instance, consider a package delivery service that accepts a package on Monday and promises to deliver a package by Thursday. If the service manages to deliver one day earlier than expected (Wednesday), the customer should not be too upset. Customer dissatisfaction will only result especially if delivery occurs later than the expected delivery day. The variability of processes can therefore be alternatively characterized based on *reliability* (Ebeling 1997)—the extent to which a system performs its required function by guaranteeing that key attributes are at acceptable levels. Reliability is determined by a customer aspiration level regarding a certain attribute (e.g., Miller and Leiblein 1996) in conjunction with observations that the attribute actually reached that level. Ultimately, whereas the concept of *variance* relates to any deviation from initial expected levels, the concept of *reliability* relates strictly to the "downside risk" that a given attribute will *not* be found at a satisfactory level or magnitude.

#### Variability and Contractual Hazards

We identify two types of hazards that arise when firms attempt to reduce variability by either reducing variance or increasing reliability in their production processes: maladaptation and underinvestment in assets that help monitor and control these processes.

*Maladaptation.* Efforts to create products or services characterized by low variability drive the development of production processes that ultimately are particularly sensitive to exogenous disturbances, i.e., variations in the environment that cannot be entirely foreseen (Williamson 1991; see also Rhee and Haunschild 2006). For instance, a sudden increase in the demand for transportation services might make it more difficult for a package delivery company to recruit independent truckers, and hence cause delay in the delivery of packages.

As a consequence, delivery time may deviate from what was expected at the outset. Such deviations are inconsequential when firms do not pursue low variability, but their consequentiality grows as firms aim to develop a reputation for low variance or high reliability in delivery time. In this context, production processes should be able to quickly detect disturbances and adopt measures to avoid deviations and meet initial aspiration levels. The inability of processes to adapt optimally results in maladaptation costs, which include devaluation of reputation, real and opportunity costs associated with reworking or disposing of products with nonconformities, and warranty costs.

*Underinvestment.* Efforts across design and production activities that can reduce variability generally can be classified as customized up-front investments or ongoing practices that monitor production, identify quality drivers, and adapt the production process. One example of up-front investment is customized inspection stations and production lines that are developed specifically to be more responsive to disturbances, thus quickly detecting, correcting, and avoiding nonconformities. As a result, the range by which an attribute deviates from its standard will shrink (i.e., variance will decrease), and initial aspiration levels of quality will more likely be met (i.e., reliability will increase). Another example of such investment is IT systems that record, transmit, and store information collected from production processes. By increasing the amount of information regarding those processes, IT systems allow managers to quickly and more sensitively detect nonconformities, thereby allowing for faster corrections. Like inspection stations, the software and hardware configurations of IT systems are tailored to the specific product and production process, oftentimes linking several activities involved in the process (Zaheer and Venkatraman 1994).

Concurrent engineering, which can ensure that component specifications are shaped simultaneously by both design and manufacturing, provides an example of ongoing practices that can also reduce variability. Failure to coordinate component and product design with manufacturing may yield a prototype that is difficult to manufacture and assemble, leading to unsatisfactory or inconsistent batches of product (e.g., Hartley 1998). Alternatively, SQC can be tailored to identify sources of variability by monitoring processes to catch product nonconformities before they reach the end user. Such practices not only require dedicated time and effort between departments to solve ongoing problems, but also induce a complex process of learning by doing, where parties develop knowledge that is specific to the process and product at hand.

Because of the particularistic nature of the necessary adjustments, both up-front and ongoing investments to increase reliability or decrease variance tend

to be highly specialized, leading to the hazard of holdups (Klein et al. 1978, Williamson 1985). Transaction cost economics asserts that contractual partners—under the assumption of opportunism—are inclined to stall the transactional process to expropriate quasi-rents from non-redeployable investments (Williamson 1985). In combination with bounded rationality (Simon 1961), which generally implies that contracts are incomplete, the fear of opportunism may make firms reluctant to make specific investments in the first place, which leads to underinvestment in those idiosyncratic product design and production processes that lower variance or heighten reliability. In exchanges where specificity is low, holdup concerns are not present because resources are redeployable, and therefore can serve other purposes or other relationships. Thus, the underinvestment hazard is inconsequential when investments are not specific, but grows as variability-reducing idiosyncratic assets are required.

### Mitigating Hazards Through Organization Form

Williamson (1985, 1991) argues that each organizational mode differs in its costs and competencies to reduce exchange hazards. Under spot markets, low variability is usually very difficult to support because specific investments will be required to some degree. So, we focus on the decision between “outsourcing” based on formal contracts with external parties, which we refer to as *contracting*, and formal equity-based control of activities along the value chain, which we term *ownership*. For simplicity, we do not distinguish between the effects of varying levels of ownership (Gulati and Singh 1998); we suppose that the stakes involved in the ownership mode are sufficient to grant effective control rights over the associated activities in the value chain. The net effect of these instruments is that contracting allows for autonomous adaptation (that is, parties to an exchange can reposition at low cost by seeking out alternative trading partners should problems arise) but performs relatively poorly at coordinated adaptation (that is, parties to an exchange find it costly to coordinate their adjustments should problems arise) (Williamson 1991). Ownership, however, is plagued by costs associated with control mechanisms and internal regulations; thus, compared to contracting, organization modes based on ownership are more costly to set up and run.

We can use Williamson’s (1991) comparative discrete analysis to assess which organizational form is more efficient with respect to the two types of hazards mentioned above. First consider the maladaptation hazards. We submit that contracting is inefficient compared to ownership for providing rapid adjustment to the growing number of consequential disturbances associated with stricter production or delivery specifications. In fact, the mere existence of contract clauses can actually *increase* disputes arising from disturbances because parties have more grounds for disagreement over how performance

should be measured or what penalties should instead be in place (Klein 1996). Yet, more generally, when the sources of environmental disturbances are various, unpredictable, and consequential, it is cumbersome to write, negotiate, and enforce a complete and fair contract that accommodates and considers all possible contingencies (Tirole 1999), especially those that are outside the control of either party. For example, CAT Telecom was unsure whether to impose its fine of 90 million baht per day on Huawei Technologies for late delivery of the first phase of a Code Division Multiple Access (CDMA) mobile phone network after the company claimed that flooding had caused the delay (Tortermvasana 2007).

Contracts are also often costly when contractual clauses are excluded or otherwise left out. Suppose that a firm crafts a contract with a supplier that specifies desired product attributes and imposes a large penalty if the supplier fails to meet a tight range of product specifications. Unforeseen contingencies will plague suppliers' ability to meet those tight specifications (e.g., a sudden shortage in the supply of high-quality components). Suppliers may satisfy the requirements on attributes specified in the contract but at the expense of detrimentally reducing or even eliminating effort associated with unspecified product attributes (Holmstrom and Milgrom 1991). Consider the outcome of Huawei's delivery of the second phase of the CDMA network. Although Huawei delivered on time for the second phase, and CAT Telecom's inspection committee had argued that testing all of the 800 switching and base stations took time, they were unable or unwilling to affirm that all stations were "functional," even weeks after inspections were completed (Tortermvasana 2007). For such situations where products or service attributes are complex and multifaceted, it will be difficult to precisely evaluate whether contract terms have been met, and then inefficient haggling and disputes are likely to arise.

Williamson (1985, 1991) insists that ownership provides the distinct mechanism of fiat to solve disputes and adapt to exogenous disturbances. Compared to contracting, where adaptation to disturbances oftentimes requires constant renegotiation, fiat exercised by one party avoids inefficient haggling and costly changes of contractual terms. For instance, a shortage in the supply of a component may trigger costly renegotiation of an outsourcing contract if an existing supplier claims to have a higher bid elsewhere. If the buyer does not agree to renegotiate, the supplier can act opportunistically by reducing the quality of the component. Given a situation of scarcity, the buyer will have difficulty finding an alternative supplier with the desired quality level. Thus, the need to adapt to external shocks will mandate added costs to renegotiate or replace existing contracts. In case of maladaptation, the buyer will likely face an increase in the range of component attributes that are deemed unsatisfactory. In contrast, if the buyer controls the supply

stage, the issues and conflict resolution modes will be of different natures. Instead of contracts, managers will need to establish transfer prices across divisions (Barney and Hesterly 2005). Managers will tend to adopt certain targets (e.g., on a cost-plus basis) and then leave exceptions to be solved through committees and internal dialogue. In outsourcing schemes, by contrast, renegotiations may be seen as something adverse. Thus, ownership becomes more efficient than contracting as production processes become more sensitive to disturbances due to the pursuit of low variance or high reliability (also see Richardson 1996).

Now consider the underinvestment hazards. In exchanges where idiosyncratic investments are not required, holdup concerns are not present because resources are redeployable and can therefore serve other purposes or other relationships. Contracting offers a more efficient form of governance for this case because there is less cost to set up and carry out transactions, whereas the coordinated adaptation advantage of ownership offers little value at high cost because there is no hazard to be mitigated. However, the appropriate organizational mode changes as specific investments become required. Recall that improved responsiveness to external disturbances will likely require investment in infrastructure (e.g., IT) and ongoing practices (e.g., routines for process control), which are fundamentally idiosyncratic. Although relatively inexpensive to set up, contracting gives rise to holdup costs, which causes underinvestment. For instance, a buyer may refuse to invest in IT systems to control processes tailored to one or more suppliers if there is a risk that these suppliers will seek to renegotiate contractual terms in such a way that the buyer will be disfavored. Ownership greatly weakens the desire for trading parties to act opportunistically when specific assets are required. Combined with the availability of fiat to resolve disputes and procedures to monitor decisions, ownership allows for investment in variability-reducing assets without the fear of holdups that markets tend to have. The resulting firm-specific investments in infrastructure and ongoing practices allow the firm to quickly identify and respond to disturbances. In conclusion, we propose the following:

**PROPOSITION 1.** *Compared to contracting, ownership of relevant activities along the value chain is associated with lower variability of product and service attributes, expressed by lower variance in those attributes and higher reliability.*

## Industry Context: The IC&SP Service Industry

We focus on IC&SP services in Japan as the domain of our study. Twenty-four firms compete in this market.

The IC&SP service industry in Japan is a desirable market to test our proposition that ownership affects variability, for several reasons. Perhaps the most important reason is that variability of a particular attribute, delivery time, is a key competitive factor in this business segment (see Rivkin 1998). Simply, the ability to deliver a parcel with higher reliability and lower variance in delivery is an important performance measure in transportation industries (e.g., Vromans et al. 2006).<sup>3</sup> The industry is also attractive for our study because there is heterogeneity in the performance attribute of delivery time. As stated earlier, we are interested in assessing how actual performance (delivery time) deviated from initial expectations. A sample of shipments therefore allows us to assess how the distribution of those observed deviations varies according to alternative ways of organizing the value chain. Much of the nature of dispersion in delivery time cannot be attributed to obvious causes such as the distance from the origin to the destination. Thus, delivery time can be considered as the realization of some stochastic process of which variability derives from additional factors that cannot be entirely foreseen. For instance, a sudden increase in the quantity of shipments using a particular airport should cause unexpected delays and contractual readjustments.

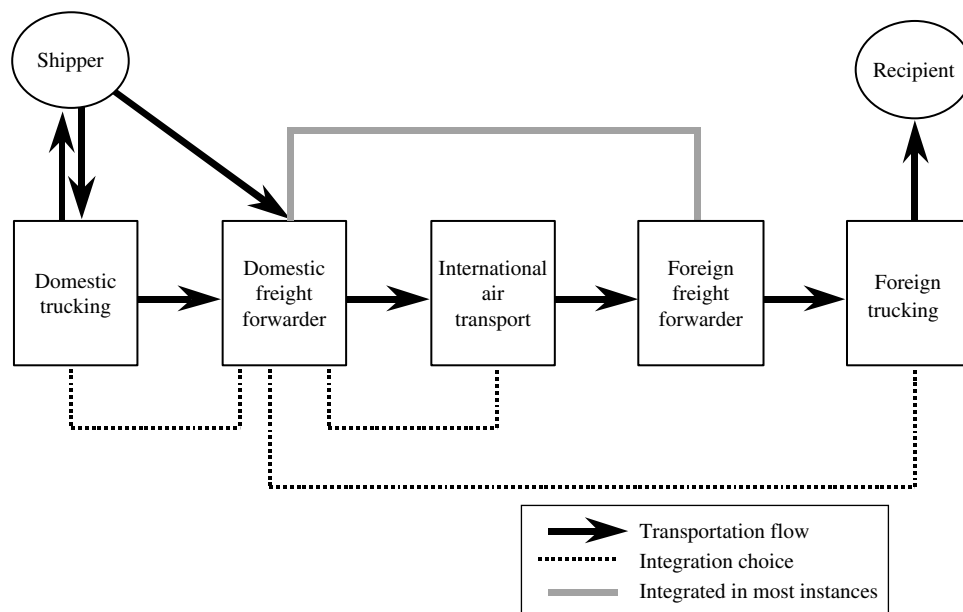
In addition, IC&SP service is comprised of five separate activities, which limit the number of transactions to be analyzed (see Figure 1). The set of transactions in the transportation chain are as follows: (1) a domestic truck picks up a parcel<sup>4</sup> from a shipper (the sender of a parcel) and transports the parcel to an airport; (2) a freight forwarder advances the parcel through domestic customs and consolidates it for air transit; (3) an international air courier flies the parcel to a foreign airport; (4) a foreign

freight forwarder advances the freight through customs and separates parcels; and (5) a foreign truck delivers the parcel to its final destination. We focus on three of these five transactions—domestic trucking, international air carriage, and foreign trucking—because the shipper typically contracts with a freight forwarder (hereafter referred to as a courier) that coordinates transportation, and we find that domestic and foreign freight forwarding activities in almost all cases are jointly owned or organized through some type of equity relation. Limiting the ownership patterns considered in the study facilitates our analysis.

Firms also employ different organizational forms to transport parcels, allowing us to relate variability to organizational choice. Basically, activities can be managed through ownership of sequential transportation segments or contracts. In most cases, freight forwarders choose ownership for some domestic trucking routes while contracting for other trucking routes.<sup>5</sup> Ownership and contracting can be found in all the three transportation segments and can vary by route (origin–destination city pair) even within the same courier. Typically, instances of ownership in our database involve a vertically integrated subsidiary dealing with a particular transportation segment, though in some cases ownership is partial (e.g., the UPS-Yamato joint venture in Japan). Even in cases of partial ownership, however, operations can be considered as “integrated” because parties typically have control rights of the corresponding operations.

The mechanisms that we use to support our proposition that ownership diminishes variability are also particularly relevant to key features of IC&SP services. These services must be coordinated according to complex logistics. Operations span multiple countries, thus

Figure 1 IC&SP Service Value Chain and Organization Alternatives



increasing the number of contingencies that managers must deal with in their day-by-day activities. External disturbances tend to be acute in this context. Furthermore, origin and destination countries are likely to differ in terms of economic, institutional (e.g., regulations), and environmental (e.g., weather) conditions. All of these factors lead to a great deal of contractual incompleteness in transactions involving IC&SP services. Ownership allows more effective adaptation to external disturbances, which are difficult to predict and specify through contingent contracts. It is true that the attribute examined in this study derives from a readily observable variable, *delivery time*. However, the overall performance of courier services derives from other dimensions as well, which causes problems for the use of contingent contracts. Thus, if a firm contracts a courier and pays in a fashion inversely related to delivery time, the latter will actively pursue quick delivery at the expense of other difficult-to-measure dimensions, such as proper handling of parcels and custom service, which affect the sender's reputation (Holmstrom and Milgrom 1991). Indeed, some companies like Federal Express (FedEx) will often attempt to use fiat-oriented mechanisms to coerce contractors to behave in standardized manners. Thus, outsourced workers at FedEx "have alleged that [the company] controls virtually every aspect of contractors' work, from the wearing of uniforms to delivery routes" (Dade 2007, p. A4; Wood 2005). Of course, although a firm may rely on contracting but then attempt to invoke fiat and impose specific work standards, it cannot do so without penalty: the Internal Revenue Service has assessed FedEx's back taxes at \$319 million for claiming to use contractors when it was actually relying on employment relationships (Dade 2007).

Finally, one particular strategic resource employed by couriers is fully consistent with our hypothesized indirect mechanism creating a negative association between ownership and variability. Executives from leading courier firms like Federal Express, UPS, and Airborne Express, all of which compete in the Japanese IC&SP service market, claim IT as their most important strategic asset, being at least as important as transportation resources (e.g., Maglitta 1991). IT resources include mobile communications for trucks, input/output devices for tracking packages, computers and networks, and software. Many, but not all, of these components that make up courier IT systems are idiosyncratic. More importantly, the ownership of these components to make them work together as a single system can be substantial and is highly idiosyncratic (Nickerson et al. 2001).<sup>6</sup> Ownership can play a role by safeguarding these investments against expropriation hazards that are likely to occur in other types of arrangements. Because those investments are likely to heighten reliability or diminish variance, a negative (positive) association between ownership and variance (reliability) should be expected.

## Data and Methods

We employ the same database used by Nickerson et al. (2001), which was collected jointly with the Institute for Telecommunications Policy (IPTP) in Japan. The data are comprised of information on parcels shipped from 37 different origin cities in Japan to 160 destination cities in 42 countries. Thirteen IC&SP couriers accomplished those shipments during February and March 1998.<sup>7</sup> Notice therefore that the parcel is our unit of analysis. In particular, we use information about the elapsed delivery time and organizational choice—contracting versus ownership—of each of three transportation segments: domestic trucking, international air transportation, and foreign trucking.

## Dependent Variable

Observing delivery time alone can be misleading. Clients may hire a particular courier expecting an extended delivery time—for instance, in cases where distances are long or where the service involves packages that do not need to reach the destination in a short period of time. Thus, we should consider *deviations* from expectations of delivery time created at the time the service is hired. Unfortunately, such expectations are often difficult to observe. To circumvent this limitation, we infer expectations of delivery time based on a set of parcel- and courier-specific variables that should strongly influence the difference in days between parcel pick-up time at the origin and drop-off time at the destination. We then compute the extent of deviation from the expected delivery time of parcels after those parcel- and courier-specific control variables have been accounted for. More precisely, we first take the natural logarithm of delivery time,  $LnDays$ , to generate the variable because of kurtosis in the data. Making the distribution more symmetric should facilitate our subsequent analysis of changes in the overall density. Next, we regress the control variables against  $LnDays$  and compute the residuals, which serve as measures of deviations from expected delivery time given courier- and parcel-specific factors. The regression model, estimated through ordinary least squares (OLS), is

$$\begin{aligned} LnDays_i = & \gamma_0 + \gamma_1 Dist_i + \gamma_2 Doc_i + \gamma_3 MarkSize_i \\ & + \gamma_4 FinCities_i + \gamma_5 DJapan_i \\ & + \sum_{m=1}^{13} \gamma_{m+5} F_{im} + e_i, \end{aligned} \quad (1)$$

where  $i$  indexes the parcels. Deviation from delivery time, referred to as  $LnDaysDev$ , is simply the residual  $\hat{e}_i = LnDays_i - LnDaysHat_i$ , where the latter refers to the fitted values of  $LnDays$  according to the regression. In our analysis, we would like to observe how the overall dispersion of deviation behaves according to distinct organizational modes. This construction allows us to



examine changes that occur on both the positive ( $\hat{e}_i > 0$ ) and negative ( $\hat{e}_i < 0$ ) sides of the distribution of deviations, thereby providing a more complete picture of the effect of ownership. Alternatively, given that customers will be dissatisfied only if the parcels arrive later than expected, we could have considered only positive deviations and treated all cases where  $\hat{e}_i$  turns out negative as equivalent to  $\hat{e}_i = 0$ . Although we concur that customer dissatisfaction will result especially if delivery occurs later than the expected day, we decided to observe both positive and negative deviations for two reasons. First, in our context, negative deviations can also be detrimental to firm performance insofar that repeated early delivery causes customers to begin raising expectations for the earliness of future deliveries, thereby setting a higher standard for future firm performance (see Rhee and Haunschild 2006). Second, by analyzing both positive and negative deviations, we provide and illustrate a methodology that can be applied in other industrial contexts where negative dispersion is particularly critical (e.g., the example of the batch of alarms discussed earlier).

The control variables employed in Model (1) are explained as follows.

*Dist.* We control for the distance the parcel travels because delivery time is expected to increase with the distance from the origin to the destination, which may cause the density to vary with distance. *Dist* is the spherical distance between origin and destination points in miles divided by 1,000.

*Doc.* The industry typically classifies shipments into documents or packages. Documents involve legal paperwork, contracts, and papers, whereas packages involve diverse items such as compact disks, product samples, parts, etc. We expect that documents, based on their typical contents, require higher real-time tracking needs, because slow or late delivery imposes larger opportunity costs on shippers and recipients compared to packages. The different requirements may affect initial expectations of delivery time because a courier may devote more attention to the transportation of documents than packages due to higher customer requirements. We code the dummy variable *Doc* 1 if the parcel is a document, and 0 if it is a package.

*MarkSize.* The size of the market to which parcels are sent may influence expectations of delivery time because large markets tend to allow for higher scale and learning-by-doing economies, thereby facilitating the coordination of shipments to those markets. *MarkSize* measures the total amount of shipments, in cumulative weight (billions of kilograms), involving international air transportation from Japan to each destination country. The most recent data for which there is information on this variable is from 1995.

*FinCities.* Based on interviews with couriers, Nickerson et al. (2001) suggest that cities that are

financial centers are likely to have the most stringent requirements for delivery time. To control for this possibility, we code the dummy variable *FinCities* as 1 for the parcel destination cities of Chicago, Hong Kong, London, Los Angeles, New York, San Francisco, and Singapore, and as 0 otherwise.

*DJapan.* Firms originally established in Japan may have local knowledge and facilities that should either help expedite shipments or reduce the set-up costs to vertically integrate some activities such as domestic transportation. To control for this effect, we add the variable *DJapan*, which is coded as 1 if the firm is originally Japanese, and 0 otherwise.

The dummy variables  $F_1, F_2, \dots, F_{14}$  represent the 14 couriers in our sample and control for courier-specific effects. For instance, certain couriers may have distinctive (unobserved) capabilities to manage the transportation of parcels, and advertise their services as such. For those couriers, expectations of delivery time should be lower, all else being equal. The variable  $F_m$  takes a value of 1 if courier  $m$  accomplished a certain shipment, and 0 otherwise.

### Independent (Organizational) Variables

To test our proposition that organizational form affects reliability and variance, we use information about the organizational form employed by couriers to transport a certain parcel, defined here as *ownership patterns*, along three transportation segments: domestic trucking, air transportation, and foreign trucking. The database contains information on the ownership choice of each courier for each transportation segment and city pair. We classify the existence of an equity stake involved in the governance of a segment for a particular city pair as *ownership* for that segment–city pair. Otherwise, we classify the segment–city pair’s organizational form as contracting. As discussed earlier, the instances codified as ownership in our database involve cases where the firm has discretion on the decisions associated with a particular transportation segment, thereby allowing it to adapt through fiat instead of renegotiation of contractual terms (for discussion of the relationship between equity stakes and control in international joint ventures, see Geringer and Hebert 1989). In this sense, *Own(Dom)*, *Own(Air)*, and *Own(For)* are dummy variables that provide information on whether the transportation of parcels through domestic trucking, international air transit, and foreign trucking, respectively, for that city pair reflected ownership (coded 1) or contracting (coded 0). To verify the effect of ownership of the three transportation segments, we also create a dummy variable *Own(All)*, equaling 1 if ownership is used for all stages (i.e., *Own(Dom)*, *Own(Air)*, and *Own(For)* are all equal to 1), and 0 otherwise.<sup>8</sup>

## Methods

Consistent with the two complementary ways to operationalize variability discussed above—variance and reliability—we adopt two distinct methods to assess the effects of ownership patterns on the deviations between expected and actual delivery time. We first employ parametric tests to identify the specific effects of ownership on variance. We thus assume that each shipment is a stochastic realization that results in a certain deviation from expected delivery given the parcel's and the courier's characteristics (measured by *LnDaysDev*). However, this analysis necessarily obscures much information about the underlying distribution and the specific location of changes in the distribution. Specifically, in our industry context, managers may be interested in the effect of ownership on the right tail of the distribution: given that customers should not necessarily care if a parcel arrives earlier than expected, managers aiming to maximize delivery reliability likely want to reduce the mass of shipments that arrive later than expected. We thus employ nonparametric density estimation as an additional tool to evaluate changes in the probability distribution or density of *LnDaysDev* conditional on alternative ownership patterns. In our view, the two methods complement each other. Nonparametric density estimation assesses changes in reliability conditional on alternative ownership patterns, and parametric tests provide statistical inference about differences in the variance of *LnDaysDev* due to those patterns.

### Parametric Tests: Assessing Variance

We assess how organizational form affects the variance of *LnDaysDev*. Our goal is to evaluate whether the absence of a certain ownership pattern would imply an increase in this variance or not. A reduction in variance is associated with an increase in the frequency of shipments that arrive around the expected delivery time. As noted before, however, the use of variance as a single statistic does not allow us to assess the location of change in the distribution. Thus, customers may be more interested in actions that increase reliability by compressing the right tail of the distribution (i.e., reducing the occurrence of deliveries that arrive later than expected) instead of actions that compress the left tail. Nonetheless, the parametric test allows us to statistically infer whether some change in the variance of attributes has occurred or not depending on particular organizational choices. Furthermore, the technique demonstrated herein can be applied in other contexts where a reduction in the overall variance is desirable (e.g., a component whose performance cannot be higher or lower than a prespecified level).

To assess the impact of organization on the overall dispersion of delivery time, we could employ simple parametric tests of variance (DeGroot 1989). Such tests are problematic because they do not allow us to control for

other variables that may impact variance. For instance, shipments involving longer distances may be more subject to exogenous disturbances that could affect the ability of the firm to guarantee delivery in the expected time. To accommodate a host of control variables in our tests, we adopt a multivariate structure similar to a linear mixed model (Verbeke and Molenberghs 1997, McCulloch and Searle 2001). We begin by specifying our key performance variable (*LnDaysDev*), as follows:

$$E[\text{LnDaysDev} | u] = X\beta + Zu, \quad (2)$$

where  $X$  is a set of fixed (control) variables,  $u$  is a random effect with mean 0 and variance  $D$ , and  $Z$  is a set of variables that can affect the variance of *LnDaysDev* through  $u$ . The distribution of *LnDaysDev* can then be modeled as

$$\text{LnDaysDev} \sim (X\beta, ZDZ^T + R), \quad (3)$$

where  $R = \text{Var}(\text{LnDaysDev} | u)$ . In this specification, we can have common variables in both  $X$  and  $Z$ . Our objective is to include in  $Z$  a host of variables that directly affect the variance of deviations between actual and expected delivery times, including the variables coding ownership patterns along the value chain, thereby allowing us to parametrically test the effect of those variables on the dispersion of delivery time.

Instead of including in  $Z$  the dummy variables coding each ownership pattern as observed in the data—*Own(Dom)*, *Own(Air)*, *Own(For)*, and *Own(All)*—we add their predicted values based on the Nickerson et al. (2001) model of organizational choice, described in Appendix A, which was applied to the same database. In the model, a key variable affecting organizational choice is the level of investment in idiosyncratic IT used by a courier and embodied in a certain shipment. This is consistent with our earlier discussion that the variability-reducing benefits of ownership may be associated with its safeguarding of IT-related investments. The inclusion of the predicted values of the ownership variables, instead of their original values, allows us to control for potential endogeneity in the data;<sup>9</sup> namely, unobservable factors such as the intrinsic difficulty of handling certain transportation segments may be associated with both organizational form and delivery time. In addition to the ownership variables, we also add in  $Z$  the control variables *Dist*, *Doc*, *MarkSize*, *FinCities*, and *DJapan*. For robustness, these controls are also included in the matrix  $X$  (fixed effect). The estimation of the model is carried out through Bayesian methods (Arellano-Valle et al. 2007, Schafer 1998).

Our test then proceeds as follows. Basically, we perform an analysis of components of variance by comparing the residual variance of the linear mixed model (i.e., the variance that remains unexplained) with and without the focal variables related to each ownership pattern. Because the absence of the focal variable in the

model is equivalent to the case where ownership of the corresponding segment is not observed, this comparison indicates how the residual variance changes due to ownership. Following Searle et al. (1992), we compute the ratio of the estimated residual variance with and without the inclusion of the focal (ownership) variables on the random-effect matrix  $Z$ . This ratio exhibits the following distribution:

$$\frac{\hat{\sigma}_{k-1}^2}{\hat{\sigma}_k^2} \sim F(n - k_k, n - k - 1), \quad (4)$$

where  $k$  is the number of explanatory variables,  $k_k$  indicates the number of model parameters with  $k$  variables, and  $n$  is the number of observations. A standard  $F$  test can then be applied to assess whether each ownership pattern significantly affects variance or not.

We report results were the conditional distribution of  $\text{LnDaysDev}$  specified in (3) is assumed to be normal. For robustness, we also perform alternative estimations with other specifications for the distribution, namely,  $t$ , skew-normal, and skew- $t$ . We find that the group of significant variables does not change when these alternative distributions are used. (Results are not reported here, but are available upon request.)

### Nonparametric Density Estimation: Assessing Reliability

Nonparametric density estimation generates an estimated sample distribution without distributional assumptions about the underlying stochastic variable. A central decision in using such a method is the specification of both a bandwidth  $h$ , within which observations will be clustered to generate a bin, and a kernel function  $K(y)$ , where  $y$  is the variable of interest, to smooth the estimates. The kernel function is any function such that  $\int_{-\infty}^{\infty} K(y) dy = 1$ . Thus, supposing that  $Y_1, Y_2, \dots, Y_N$  are realizations of some variable  $y$ , a kernel density estimator can be generically defined as

$$\hat{f}(y) = \frac{1}{N} \sum_{i=1}^N \frac{\theta}{h} K\left(\frac{y - Y_i}{h}\right). \quad (5)$$

This is the so-called Rosenblatt-Parzen density estimator, adapted to include a weight  $\theta$  indicating the inverse probability that each observation will be sampled (Johnston and DiNardo 1997). As we discuss later, this weight plays an important role in our analysis. Because shipments differ in terms of relevant attributes, each parcel is more likely to be transported according to a particular organizational pattern depending on these attributes. These shipment attributes should be taken into account in the estimation of densities that are conditional on the choice of a certain organizational pattern.

To estimate (2), it is necessary to select a particular form of the kernel function  $K(\cdot)$  and bandwidth  $h$ . Although there are several kernels that can be used

(see, e.g., Silverman 1986), we employ in our analysis the Epanechnikov kernel:  $K(z) = 3(1 - z^2/5)/(4\sqrt{5})$  for  $|z| < \sqrt{5}$ , and 0 elsewhere. The choice of the Epanechnikov kernel is justified by its asymptotic optimality based on the criterion of integrated mean squared error, which defines the expected value between the true data distribution and the distribution obtained by the kernel estimator (Epanechnikov 1969). Some authors, however, remark that the choice of the bandwidth  $h$  is relatively more important than the choice of the kernel function (Johnston and DiNardo 1997). Choosing an “optimal” bandwidth requires the recognition that a large bandwidth generates a smaller variance but with potential bias, whereas a narrow bandwidth reduces the bias of the estimation but with greater variance. To compute this “optimal” bandwidth, we employ a formula presented in Fox (1990).<sup>10</sup>

Our goal is to answer the following question: What would the *distribution* of the deviations relative to expected delivery time look like had all parcels been transported through a particular organizational form? Typical studies relating organizational form to performance would answer instead the following question: What would the *expected value* of the deviation relative to expected delivery time look like had all parcels been transported through a particular organizational form? Thus, our study shifts the focus of the attention from expected performance to the overall distribution of performance. Following DiNardo et al. (1996), we want to compute a *counterfactual* density that estimates the distribution of the whole sample by supposing that the data were generated through a particular process—in our case, a specific ownership pattern. This counterfactual density can then be compared to the density of the whole sample to visualize how a distinct ownership pattern would change the original distribution of delivery time. In particular, our goal is to assess changes in reliability, i.e., whether or not ownership induces a skew in the distribution of delivery time through a compression in its right-hand portion (parcels that would otherwise arrive later than expected).

We use the method suggested by DiNardo et al. (1996) to estimate counterfactual densities (see also Johnston and DiNardo 1997, pp. 376–379), which is exemplified in Appendix B. A critical aspect of the method is how to compute the weight  $\theta$  of Equation (5). To carry out this computation, we again make use of the Nickerson et al. (2001) model of organizational choice, described in Appendix A. Weighting is crucial in this context because, if IT-related investments are associated with ownership, shipments that do not involve those investments are likely to be underrepresented in any subsample where there is some form of ownership, thus biasing estimates that do not take this effect into account. To compute the weights, we use the results of probit models to generate predicted values for the probability

that a certain parcel will be transported through ownership of domestic trucking ( $Own(Dom) = 1$ ), air transit ( $Own(Air) = 1$ ), foreign trucking ( $Own(For) = 1$ ), and all segments ( $Own(All) = 1$ ), given a vector of shipment attributes  $x$ . This generates, for each ownership pattern, the conditional probability  $Pr(Own(\cdot) = 1 | x)$ . We then compute the proportion of observations that follow a certain ownership pattern. In the sample, 70.1%, 43.2%, 69.9%, and 35.2% of parcels were transported through ownership of domestic trucking, air transit, foreign trucking, and all segments, respectively. This generates the unconditional probability  $Pr(Own(\cdot) = 1)$ . Weights for each ownership pattern are then simply computed as  $Pr(Own(\cdot) = 1) / Pr(Own(\cdot) = 1 | x)$ .

Following this procedure, we estimate counterfactual densities for the following patterns: ownership of domestic trucking ( $Own(Dom) = 1$ ), air transportation ( $Own(Air) = 1$ ), foreign trucking ( $Own(For) = 1$ ), and all segments ( $Own(All) = 1$ ). The analysis of the first three counterfactual densities allows us to visualize changes in the distribution if all parcels were sent through ownership of *at least* the indicated segment, whereas the fourth counterfactual density will allow us to see expected changes supposing ownership of *all* segments.

A shortcoming of the procedure described above is that it does not control for biases due to couriers' self-selection of organizational form. Unobservable factors may be correlated with both the choice of ownership and disturbances that induce deviations between expected and actual delivery times, thereby potentially biasing the estimates. Carneiro et al. (2003) have extended the DiNardo et al. (1996) procedure to control for self-selection by using a latent factor structure to account for unobservable variables that may cause self-selection bias. We implemented the Carneiro et al. (2003) method in our data and then carried out a statistical test by comparing the unrestricted model with the latent factors to the restricted model without latent factors corresponding to the original DiNardo et al. (1996) procedure. The test suggests that the DiNardo et al. (1996) method is apparently appropriate to estimate the counterfactual densities in our study. More details are included in Appendix C.

## Results and Discussion

### Computing $LnDaysDev$

OLS estimates of Model (1) are presented below, involving a total of 764 parcels (standard errors are in parentheses).<sup>11</sup>

$$LnDaysHat_i = -1.188 + 0.097Dist_i - 0.047Doc_i \\ (0.095) (0.013) (0.063) \\ - 0.013MarkSize_i - 0.184FinCities_i + \\ (0.003) (0.044)$$

$$- 1.398DJapan_i$$

$$(0.172)$$

+ Courier-specific effects

$$R^2 = 0.401, p > F = 0.000. \quad (6)$$

All control variables are significant at a 1% level except *Doc*, which is not significant. Although distance increases delivery time, destination cities that are financial centers and have large markets decrease it. As expected, firms originally established in Japan exhibit shipments with lower delivery times. Courier-specific dummies are not reported in Equation (5) for simplicity, but they were all significant at a 1% level. Using the regression results presented in (5), we compute  $LnDaysDev = LnDays - LnDaysHat$ , which is equal to the estimated error term of (1).

### Results Parametric Tests: Assessing Variance

Table 1 reports the results of the parametric test assessing the effect of ownership variables on the residual variance of  $LnDaysDev$  after we eliminate the effect of (fixed) control variables. Due to missing data on organizational choices and other variables used to estimate predicted organizational patterns—derived from the estimation of the Nickerson et al. (2001) model (Appendix A)—we reduce the number of observations to 565.

Results indicate that ownership of domestic trucking and ownership of all segments significantly reduce residual variance by 12% and 13.5%, respectively ( $p < 0.05$ ). As for the other ownership patterns, the effect is insignificant. However, the larger effect provided by multiple ownership suggests that control of other segments has some, albeit small, interaction with ownership of domestic trucking. In other words, ownership of air transportation and foreign trucking apparently only matters if ownership of domestic trucking is present; and the bulk of the variance-reducing benefits of ownership occur in the domestic trucking segment. Possibly, ownership of domestic trucking allows couriers to more closely control the initiation of shipments, with a positive impact on

**Table 1 Parametric Test to Assess the Effect of Alternative Ownership Patterns on the Variance of Deviations Between Actual and Expected Delivery Times**

Ownership pattern	Residual variance		F	p value
	With ownership variable	Without ownership variable		
Domestic trucking	0.233	0.261	1.119	0.047
Air transportation	0.256	0.261	1.018	0.210
Foreign trucking	0.258	0.261	1.011	0.225
All segments	0.230	0.261	1.131	0.038

Note.  $N = 565$ .

the attainment of initial expectations in terms of delivery time.

It would be premature, however, to conclude that ownership of air transportation and foreign trucking has no sizeable effect on variability. The variability-based benefits of an organizational form should not be assessed solely through observed reductions in a single parameter such as variance, which obscures information about the underlying distribution of performance. Thus, even though ownership of a particular segment has no significant effect on the variance, it may affect in a certain way the overall shape of the underlying distribution of *LnDaysDev*. This is what we observe next, with the non-parametric method of density estimation.

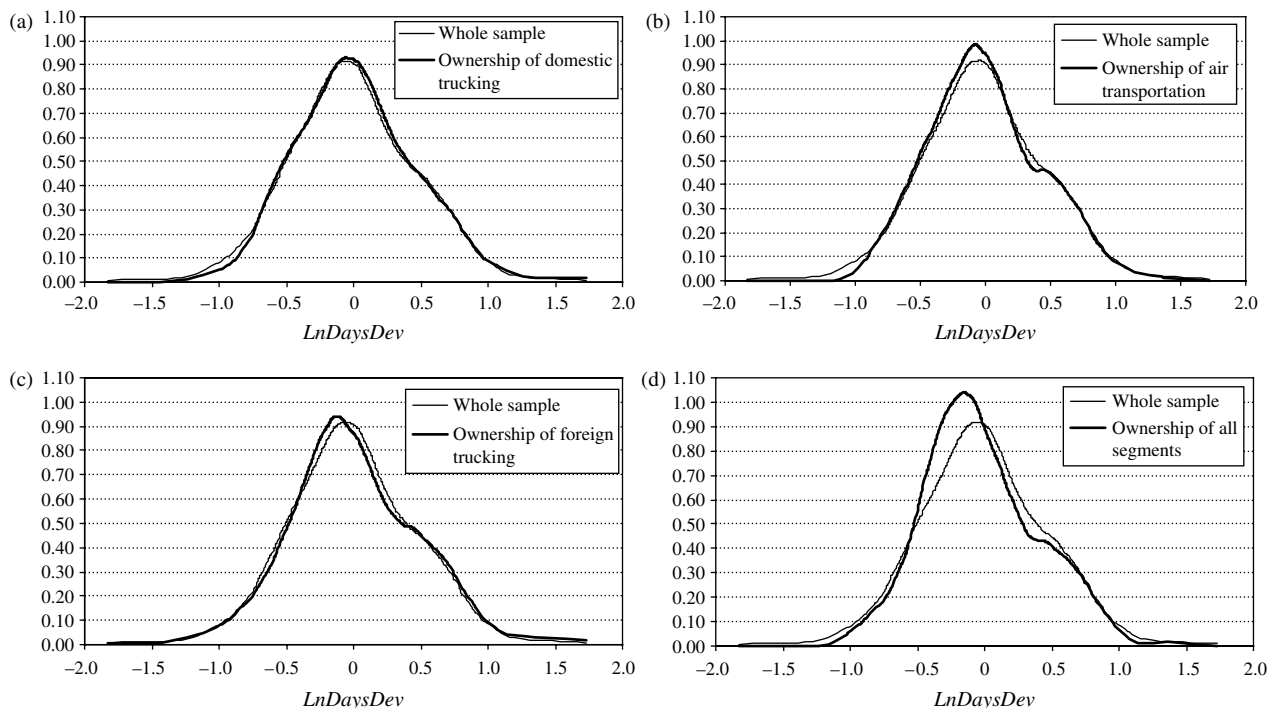
**Results of Estimated Densities: Assessing Reliability**

The estimated densities are presented in Figure 2. For each ownership pattern, we compared the estimated density of the whole sample (thin line) to the weighted counterfactual density for each ownership pattern under consideration (heavy line). The counterfactual density is the distribution of *LnDaysDev* had all parcels been transported through ownership of the segments indicated in each graph. Figure 3 presents the same densities in differential form, i.e., the difference between the density of the whole sample and the counterfactual density for each ownership pattern. Using those differences, it is easy to observe in which *region* a particular organizational form is expected to change the density (DiNardo et al. 1996). For example, positive values or peaks of those difference lines at a particular level of *LnDaysDev* indicate that a

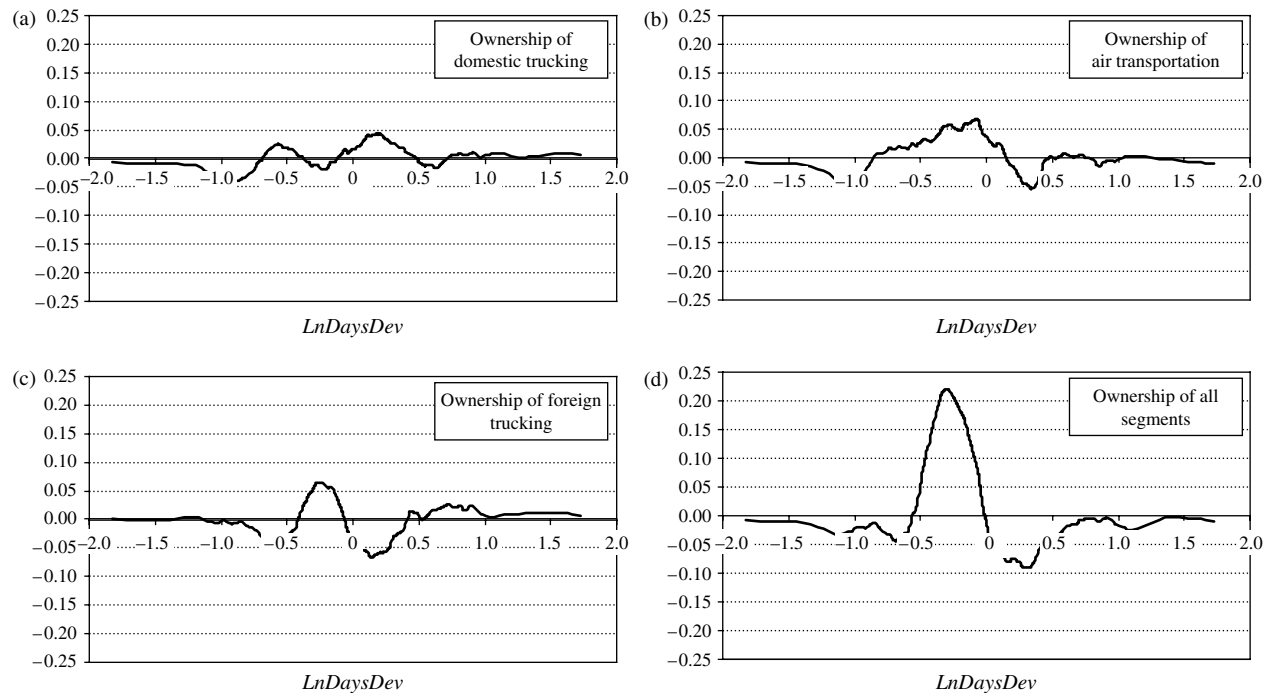
certain ownership configuration would increase the mass of shipments around that level of performance (deviation from expected delivery) compared to the whole sample. Kolmogorov–Smirnov tests reject the equality of the original and the counterfactual distributions at a 1% significance level. Thus, in all cases, changes are statistically significant, although they differ in terms of their magnitude and location in the distribution.

The examination of Figures 2 and 3 shows that ownership of each transportation segment promotes distinct changes in the density and, in turn, distinct effects on reliability. Had all parcels been transported subsuming domestic trucking under ownership, there would be a decrease of shipments arriving significantly earlier than expected, represented by the mass at the lower tail (Figure 3(a)). Therefore, in terms of reliability, ownership of domestic trucking does not appear to yield substantial benefits: it does not substantially affect the mass of shipments that would otherwise arrive later than expected. In contrast, ownership of air transportation appears to compress the distribution toward the median value of the original distribution (i.e., the density for the whole sample). It is associated with a decrease in the mass of shipments arriving particularly early (the lower tail), but also with a decrease in the mass of shipments arriving slightly later than expected (as shown by the “valley” between 0 and 0.5 in Figure 3(b)). Ownership of the foreign trucking segment exhibits a similar effect, except that there are no substantial changes at the tails (see, in particular, Figure 3(c)). In other words, the reliability-increasing properties of air transportation and foreign

**Figure 2** Estimated Counterfactual Densities for Each Ownership Pattern Compared to the Density of the Whole Sample



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**Figure 3** Difference Between the Counterfactual Density for Each Ownership Pattern and the Density of the Whole Sample

trucking ownership tend to apply mainly to shipments that would arrive slightly late. In both cases, however, changes are not substantial.

Figures 2 and 3 also suggest that there is an interaction effect involving ownership of multiple segments. Changes are apparently more pronounced when ownership applies to the whole chain; compare, in particular, Figure 3(d) to Figures 3(a), 3(b), and 3(c). Ownership of the whole value chain is associated with the highest increase in the mass of shipments with deviations from expected delivery time that fall immediately below the median of the original distribution. There is also a reduction in the mass of shipments that would arrive late, as evidenced by the compression of the upper tail. However, ownership of all segments also compresses the lower tail—an effect probably due to domestic trucking and air transportation (see Figures 2(a) and 2(b)). As a whole, ownership of all segments appears to compress the density into a range of delivery performance just below the median of the original density. In other words, ownership of multiple sequential activities in the chain apparently increases reliability by reducing the incidence of shipments that would otherwise arrive later than expected.

It seems, therefore, that ownership of different transportation segments generates changes in distinct regions of the distribution. Whereas ownership of domestic transportation appears to decrease the incidence of shipments that would otherwise arrive earlier than expected, ownership of the air or foreign trucking segments appears to slightly reduce the mass of shipments that

would otherwise arrive late. A possible explanation is that disturbances that could cause substantial delays tend to occur in advanced stages in the transportation chain crossing international borders. Monitoring should be much more difficult in foreign trucking than in domestic trucking, especially insofar as cross-cultural communication and differences in behavioral norms cannot be eliminated. Specific idiosyncratic investments in information technology can then step in to help track shipments and respond to virtually all shocks. In contrast, the additional deviation in package delivery time brought about by relatively routine air transportation should crucially depend on the control rights provided by ownership. Fiat, in turn, is more likely used to correct particularly late or particularly early deliveries. The notion that integration of air transportation through fiat reduces particularly late or particularly early deliveries is supported by Figure 2(b).

Similarly to the pattern observed in the parametric tests of variance, there is also evidence of an interaction effect in the case of multiple ownership: the reliability-enhancing effect of ownership is much more pronounced when the firm controls all segments in the chain. Thus, if one wants to increase reliability—in this context, by reducing late deliveries—one should consider adopting ownership of multiple segments in the chain, provided the added costs do not outweigh the perceived benefits in terms of customer satisfaction and improved operations. Apparently, ownership of multiple activities allows firms to better deal with the myriad disturbances that could induce maladaptation—disturbances that apply in several stages of the transportation chain.

It is useful to compare the results of the nonparametric density analysis with the results of the tests of variance. Because the effects of air transportation and foreign trucking are located in that particular region of the distribution, they were not captured by the parametric test of variance described before. Apparently, ownership reduces the mass of shipments that would arrive later than most parcels (controlling for parcel- and courier-specific factors), and thus increases reliability, as shown by the leftward skew in the curve in Figure 2(c). In contrast, ownership of multiple segments appears to show an effect on *both* variance (as indicated by the parametric tests) and reliability. The overall change in the distribution observed in Figure 2(d) indicates that ownership of multiple segments causes both a leftward skew in the curve, by reducing the mass of shipments that would otherwise arrive late, and an overall compression of the distribution. Notice, in particular, the compression of both the left and the right tails of the original distribution provided by the counterfactual density involving ownership of all segments (Figure 3(d)).

It is curious to observe that the parametric tests of variance indicate a significant effect of domestic trucking ownership on variance, even though the counterfactual density depicted in Figure 2(a) show only a small effect located especially in the left tail. Thus, the effect of domestic ownership appears to be mostly due to a reduction in the incidence of shipments that would arrive too early. Ultimately, however, this effect may not be valued to customers; they should only care if the courier avoids shipments that would otherwise arrive too late. If we assess the effect of domestic trucking on variance only, we will neglect that its effect on reliability is scant. This observation shows that nonparametric density estimation and parametric tests of variance can be seen as complementary methods to assess the impact of organizational form on the reliability and variance of product performance, respectively.

We conclude that ownership has some role in reducing the variance and increasing the reliability of product attributes (in our case, delivery time). Our data show, however, that the effect of ownership is mostly pronounced when the firm has multiple ownership stakes. Thus, broad support for our proposition is found only when we consider an organizational pattern involving ownership of multiple activities in the value chain.

## Concluding Remarks

Our main contribution with this paper is to assess whether alternative organizational forms differentially support efforts to pursue low variability of production processes and product attributes. Supply chain management scholars studying operational practices whose goal is to increase reliability or reduce variance have often overlooked how organizational choices support those

practices. Also, by focusing solely on how organizational form affects average performance, organization and strategy scholars have largely neglected to examine such second-order effects.<sup>12</sup> Some scholars even suggest that theories of economic organization fail to address efforts aimed at increasing reliability and reducing variance in supply chains. For instance, Flynn and Flynn (2005, p. 3423, emphasis added) contend that “[a]lthough [transaction cost analysis] theory is widely accepted and has proved useful in a variety of contexts, it may not provide the appropriate perspective for supply chain management in the evolving global business environment. Its emphasis on costs ignores other relevant factors, *particularly related to quality*.”

To address these gaps in theory, we apply transaction cost logic to the organizational pursuit of quality (more specifically, variance and reliability of product attributes), proposing that ownership reduces maladaptation and promotes idiosyncratic investments, which help to monitor and control for shocks that may cause variation in attributes. When the trade-off of added control costs is justified, ownership should be chosen and should lead to improvements in processes generating a reduction in variability. Data from the international courier and small package services industry in Japan allow us to assess this proposition: whereas ownership of single transportation segments shows distinct (and often slight) effects on variability, ownership of multiple segments apparently yields a more pronounced effect on both variance and reliability. Thus, our data reveal variability-reducing benefits of ownership—especially when ownership is observed in multiple stages of the value chain.

We demonstrate the applicability of nonstandard methods to assess the effect of organizational choice on the variance and reliability of production processes and product attributes. The use of nonparametric density estimation techniques helped to examine the effects of alternative ownership patterns on reliability by pinpointing changes in the overall distribution of deviations for expected delivery time. The use of parametric tests complementarily allowed us to evaluate the statistical significance of the shift that ownership imparts on variance. The nonstandard techniques exemplified here can be potentially used in future studies to examine the effect of organization (or any other strategic choice) on the variability of a product’s attributes or any other performance dimension that is found to be relevant in a given context.

Of course, we should not expect to find that all companies in all industries will own activities involved in all product lines, in the name of increasing reliability or diminishing variance. A company may have slack resources available at arm’s length that reduce the need to vertically integrate (e.g., access to a large labor market, funds and policies amenable to manipulating overtime pay), instead increasing the desirability of making

research and development (R&D) investments (e.g., Kim et al. 2008). Furthermore, the company may not have the necessary competencies to deal with multiple activities. In our IC&SP case, the kind of knowledge required in successfully vertically integrating priority delivery activities is not significantly qualitatively different from the kind of knowledge required in successfully vertically integrating express delivery or regular delivery activities. To reiterate, we simply suggest that the control rights provided by ownership have improved adaptation properties in a context of frequent and consequential exogenous disturbances that cannot be contracted out at the outset. The benefits of diminished variability may indeed be outweighed by the high costs associated with ownership. Put another way, we do not seek to explain the prevalence of ownership in the IC&SP industry, only the operational performance effects of such a strategy.

Our study suffers from a few other limitations. First, the results are industry specific: as we argued, variance and reliability are important competitive variables in the courier industry, but this may not be the case in other contexts. For this reason, even if ownership reduces the variance and increases reliability in product or service attributes in other industry contexts, it may not provide any benefit in terms of distinct competitive advantage if there are no customer segments that value superior levels of either. We believe, however, that heterogeneous customer requirements in terms of reliability and variance are pervasive and particularly high when the industry or certain target markets are associated with repeated purchases of differentiated products that are closely tied to a particular brand name.

Second, as stated before, we do not have information on the costs associated with each organizational pattern. Thus, although we provide evidence that ownership allows for reliability- or variance-related benefits, the added costs incurred in the establishment and maintenance of ownership structures may supplant those benefits. For instance, Airborne Express estimates that outsourced “pickup and delivery [is] 10% less expensive than company-owned pickup and delivery” (Rivkin 1998, p. 12). An effort to collect information on governance costs would be an important extension of this study.<sup>13</sup>

Third, we were not able to identify the particular mechanism that mediates the relationship between ownership and variability. Although we do have evidence that ownership is associated with increased investments in idiosyncratic IT, we cannot be sure how significantly ownership enhances the coordination and adaptation to external disturbances. Future work may be able to tease these apart.

Nonetheless, our results point out the importance of assessing the variability of performance as a result of distinct organizational choices. Such a research endeavor is not as difficult as it seems. In nonobvious cases,

studies focusing on particular industries should verify whether these dimensions of performance are key competitive variables in the industry or in some market segments that firms could target, as in the international courier industry. Analyses of performance variability can be a natural extension of empirical studies evaluating the impact of organization on quality-based aspects of performance. Scholars interested in testing propositions related to this topic, in any case, must face the challenge of collecting sufficient data, or relying on third-party rating or certification agencies. The methods presented in this paper can then be easily applied to other contexts if one assumes that performance results from cumulative realizations of some underlying stochastic variable whose distribution can be empirically assessed.

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### Appendix A. Nickerson et al. (2001) Model of Endogenous Governance Choice

Nickerson et al. (2001) claim that a firm’s market *position* is supported by an underlying *resource profile*, which is paired with an *organizational form* to generate a performance level consistent with that position. In the database, *position* is measured as the proportion of parcels for each firm that are documents, which demand more careful handling and delivery compared to other ordinary packages. The dummy variables *DocSpec* and *PackSpec* identify a courier’s market position as a document specialist or package specialist, respectively. The courier is classified as a document specialist when 90% or more of the parcels the firm carries are documents. Similarly, the courier is classified as a package specialist when 90% or more of the parcels the firm carries are packages. *DocSpec* is coded as 1 when a courier is a document specialist; otherwise, it is coded as 0. The variable *PackSpec* is coded as 1 when a courier is a package specialist; otherwise, it is coded as 0.

*Resource profile* is measured as the level of idiosyncratic IT infrastructure in each transportation segment. Document specialists are expected to employ more idiosyncratic IT than package specialists, because their market position requires a more precise tracking of parcels from the origin to the destination. As a proxy for idiosyncratic resources, the database contains an index for each transportation segment that counts the pieces of information available from each segment to the freight forwarder. These indices assume that the level of idiosyncratic IT is positively correlated with the amount of real-time information collected in each segment. The count indices  $k_{\text{domtrk}}$ ,  $k_{\text{intair}}$ , and  $k_{\text{fortrk}}$  increase by one for each piece



of parcel-level data collected from domestic trucking, international air, and foreign trucking activities, respectively. The indices range from 0, which indicates that no data are available from the courier's information network, to 7, 8, or 7, for  $k_{domtrk}$ ,  $k_{intair}$ , and  $k_{fortrk}$ , respectively, which indicate all of the information is available on the courier's information network.

Organizational form is measured by our familiar variables  $Own(Dom)$ ,  $Own(Air)$ , and  $Own(For)$ , to which we add the variable coding ownership of all segments,  $Own(All)$ , unavailable in the Nickerson et al. (2001) analysis.

Nickerson et al. (2001) employ  $FinCities$ ,  $MarkSize$ , and  $Dist$  as control variables, which we explain in the text. They also employ an additional control variable to accommodate Williamson's (1991) point that an organization mode choice depends on the political risk engendered by a nation's institutions. To measure that risk, Henisz (1998) constructed an index ranging from zero (low risk) to one (high risk) that reflects the probability of policy changes by country. This index is labeled  $PolRisk$  in the database. Firms in higher-risk institutional environments are less likely to make specific investments for fear of public and private expropriation. Higher-risk institutional environments also may lead firms to use ownership to avoid private expropriation. To control for the effect of local ownership, we add a variable that was absent in the Nickerson et al. (2001) model:  $DJapan$ , which, as explained in the text, is a dummy variable coded 1 if the firm was originally established in Japan, and 0 otherwise. Table A.1 presents summary statistics and correlations.

The Nickerson et al. (2001) method sequentially estimates separate regression models, which in turn explain the level of idiosyncratic IT resources, the impact of this investment on a firm's choice to vertically integrate, and the relationship between hierarchy and delivery performance. The first set of equations examines the impact of market position on the level of idiosyncratic IT in each transportation segment. Let  $k_{ji}$  be the level of idiosyncratic resources for parcel  $i$ , and let  $j = \{domtrk, intair, fortrk\}$  index the transportation segment. Then,

$$k_{ji} = \beta_{0j} + \beta_{1j}PackSpec_i + \beta_{2j}DocSpec_i + \beta_{3j}Dist_i + \beta_{4j}FinCities_i + \beta_{5j}MarkSize_i + \beta_{6j}PolRisk_i + \beta_{7j}DJapan_i + \varepsilon_{ji}, \quad (a_j)$$

where  $\varepsilon_{ji}$  is a random error term. Note that (a<sub>j</sub>) models a regression equation for each of the three transportation segments. The three regression equations defined in (a<sub>j</sub>) are estimated as a system using the seemingly unrelated regression (SUR) method due to the possibility of nonzero covariances across equations. Robust standard errors are also estimated, to account for courier-level correlation.

After establishing the impact of market position on the level of idiosyncratic IT in each transportation segment, the next stage of the model examines the relationship between the extent of this investment and the organizational choice in each segment. The regression models examining the organizational choice for each transportation segment are given by

$$Own(Dom)_i = \alpha_{4,0} + \alpha_{4,1}k_{domtrk,i} + \alpha_{4,2}Dist_i + \alpha_{4,3}FinCities_i + \alpha_{4,4}MarkSize_i + \alpha_{4,5}PolRisk_i + \alpha_{4,6}DJapan_i + u_{4,i}, \quad (a1)$$

$$Own(Air)_i = \alpha_{5,0} + \alpha_{5,1}k_{intair,i} + \alpha_{5,2}Dist_i + \alpha_{5,3}FinCities_i + \alpha_{5,4}MarkSize_i + \alpha_{5,5}PolRisk_i + \alpha_{5,6}DJapan_i + u_{5,i}, \quad (a2)$$

$$Own(For)_i = \alpha_{6,0} + \alpha_{6,1}k_{fortrk,i} + \alpha_{6,2}Dist_i + \alpha_{6,3}FinCities_i + \alpha_{6,4}MarkSize_i + \alpha_{6,5}PolRisk_i + \alpha_{6,6}DJapan_i + u_{6,i}, \quad (a3)$$

to which we add

$$Own(All)_i = \alpha_{7,0} + \alpha_{7,1}k_{total,i} + \alpha_{7,2}Dist_i + \alpha_{7,3}FinCities_i + \alpha_{7,4}MarkSize_i + \alpha_{7,5}PolRisk_i + \alpha_{7,6}DJapan_i + u_{7,i}, \quad (a4)$$

where  $k_{total} = k_{domtrk} + k_{intair} + k_{fortrk}$ . Each equation is estimated using a probit model. To account for the possible endogeneity of resource profile and governance choice,  $k_{domtrk}$ ,  $k_{intair}$ , and  $k_{fortrk}$  are replaced in (a1), (a2), and (a3) by their predicted values, denoted  $k_{domhat}$ ,  $k_{inthat}$ , and  $k_{forthat}$ , respectively, generated from the estimation of the system of equations (a<sub>j</sub>). The variable  $k_{totalhat}$ , which replaces  $k_{total}$  in (a4), is computed simply as  $k_{domhat} + k_{inthat} + k_{forthat}$ . (Results, however,

**Table A.1 Model of Endogenous Governance Choice Based on Nickerson et al. (2001): Summary Statistics and Correlations**

Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 <i>PackSpec</i>	0.16	0.37	0	1														
2 <i>DocSpec</i>	0.31	0.46	0	1	-0.29*													
3 $k_{domtrk}$	4.02	2.60	0	7	-0.26*	0.60*												
4 $k_{intair}$	4.43	2.18	0	8	-0.14*	0.04	0.37*											
5 $k_{fortrk}$	5.22	2.22	0	7	-0.43*	0.45*	0.70*	0.64*										
6 <i>Own(Dom)</i>	0.70	0.46	0	1	-0.12*	0.43*	0.39*	-0.45*	0.00									
7 <i>Own(Air)</i>	0.43	0.50	0	1	-0.39*	0.39*	0.66*	0.14*	0.45*	0.41*								
8 <i>Own(For)</i>	0.70	0.46	0	1	-0.23*	0.29*	0.25*	0.31*	0.36*	-0.08	0.38*							
9 <i>Own(All)</i>	0.35	0.48	0	1	-0.21*	0.46*	0.49*	-0.22*	0.10*	0.40*	0.76*	0.44*						
10 <i>LnDays</i>	0.74	0.57	-1.47	2.20	0.46*	-0.20*	-0.19*	-0.11*	-0.29*	0.03	-0.17*	-0.13*	-0.17*					
11 <i>Dist</i>	5.02	1.63	0.75	7.50	0.12*	-0.03	-0.04	0.04	0.01	-0.09*	-0.07	0.05	0.16*	-0.06				
12 <i>MarkSize</i>	11.86	8.19	0.12	19.78	0.06	-0.03	-0.06	0.02	-0.03	-0.13*	-0.05	0.13*	-0.05	0.03	0.63*			
13 <i>FinCities</i>	0.66	0.48	0	1	0.10*	-0.04	-0.08	-0.06	-0.12*	-0.06	-0.11*	0.02	-0.07	-0.02	0.38*	0.48*		
14 <i>PolRisk</i>	0.29	0.27	0.12	1	-0.17*	0.00	0.07	-0.01	0.06	0.10*	0.12*	-0.11*	-0.07	0.02	-0.81*	-0.71*	-0.57*	
15 <i>DJapan</i>	0.28	0.45	0	1	0.49*	-0.42*	-0.58*	-0.26*	-0.67*	-0.10*	-0.55*	-0.29*	-0.47*	0.30*	0.01	0.05	0.13*	-0.10*

\* $p < 0.05$ ;  $N = 565$ .

**Table A.2 Model of Endogenous Governance Choice Based on Nickerson et al. (2001)**

Coefficients	Investment analysis			Organizational choice			
	$k_{domtrk}$	$k_{intair}$	$k_{fortrk}$	(A1) <i>Own(Dom)</i>	(A2) <i>Own(Air)</i>	(A3) <i>Own(For)</i>	(A4) <i>Own(All)</i>
<i>PackSpec</i>	0.659** (0.244)	-0.227 (0.278)	-0.713** (0.208)				
<i>DocSpec</i>	2.531** (0.187)	-0.443* (0.213)	0.918** (0.160)				
$k_{domhat}$				0.818** (0.254)			
$k_{inthat}$					1.355* (0.649)		
$k_{forthat}$						0.306*** (0.164)	
$k_{tothat}$							1.089*** (0.566)
<i>Dist</i>	0.024 (0.084)	0.012 (0.095)	0.047 (0.071)	0.033 (0.073)	-0.058 (0.094)	-0.187 (0.159)	-0.271* (0.122)*
<i>FinCities</i>	0.093 (0.205)	-0.352 (0.233)	-0.290*** (0.175)	0.025 (0.309)	0.396 (0.294)	-0.124 (0.200)	0.190 (0.269)
<i>MarkSize</i>	-0.003 (0.014)	0.004 (0.016)	0.000 (0.012)	-0.013 (0.017)	0.001 (0.015)	0.021 (0.034)	0.016 (0.029)
<i>PolRisk</i>	0.538 (0.593)	-0.565 (0.675)	-0.213 (0.506)	0.376 (0.649)	0.962 (1.020)	-1.266 (0.966)	-0.693 (0.715)
<i>DJapan</i>	-2.500** (0.210)	-1.366** (0.239)	-2.606** (0.179)	2.127* (0.981)			
<i>Constant</i>	3.536** (0.644)	5.274** (0.733)	5.813** (0.549)	-3.237** (1.076)	-6.574* (3.321)	0.137 (1.381)	-4.529 (2.925)
$R^2$ /pseudo $R^2$	0.50	0.08	0.50	0.21	0.21	0.12	0.34
$N$	565	565	565	565	565	565	565
Correlation of residuals							
$k_{domtrk}$	1						
$k_{intair}$	0.37	1					
$k_{fortrk}$	0.49	0.70	1				

\* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.10$ .

are qualitatively similar if we use instead the original variables  $k_{domtrk}$ ,  $k_{intair}$ , and  $k_{fortrk}$ .)

The results are presented in Table A.2. Due to missing data on organizational choices and other variables, the number of observations was reduced to 565. Supporting the authors' predictions, document specialists tend to employ a more idiosyncratic IT infrastructure for each segment, which in turn generally increases the probability that ownership is used for that segment. We do not discuss these results in detail because our objective is simply to use the model to compute weights for the nonparametric density estimation. It is worth mentioning that the dummy variable *DJapan* had to be removed from the estimation of (a2) and (a4), because it did not have sufficient discriminatory power; namely, all firms originally established in Japan do not have ownership stakes in the air transportation segment and, consequently, do not exhibit an ownership pattern involving all segments.

**Appendix B. Estimating Counterfactual Densities According to Distinct Ownership Patterns**

To exemplify the method (DiNardo et al. 1996; Johnston and DiNardo 1997, pp. 376–379), consider a particular

ownership pattern: consolidated ownership of all segments ( $Own(All) = 1$ ). Suppose shipments differ according to certain attributes  $x$ , distributed according to the density  $h(x)$ . We want to estimate the distribution of deviations from expected delivery time, denoted by  $f(y)$ . In our case, realizations of  $y$  are represented by  $LnDaysDev$ . The distribution of the entire sample is equal to

$$f(y) = \int_{x \in \Omega} g(y | x) h(x) dx, \tag{b1}$$

where  $g(y | x)$  is the density of deviations from expected delivery time conditional on shipment attributes  $x$ , and  $\Omega$  is the domain of  $x$ . The observed density of deviations from expected delivery time for shipments involving ownership of all segments is

$$f(y | Own(All) = 1) = \int_{x \in \Omega} g(y | x, Own(All) = 1) h(x | Own(All) = 1) dx. \tag{b2}$$

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The counterfactual density is the density that would have prevailed had all parcels been transported through vertical ownership of all segments, or

$$f^C(y | Own(All) = 1) = \int_{x \in \Omega} g(y | x, Own(All) = 1) h(x) dx. \quad (b3)$$

To estimate (b3), notice that Bayes' law implies  $h(x) = [h(x | Own(All) = 1)Pr(Own(All) = 1)]/Pr(Own(All) = 1 | x)$ . Using this fact, we modify the counterfactual density to

$$f^C(y | Own(All) = 1) = \int_{x \in \Omega} \theta g(y | x, Own(All) = 1) h(x | Own(All) = 1) dx, \quad (b4)$$

where  $\theta = Pr(Own(All) = 1)/Pr(Own(All) = 1 | x)$  is the *weight*. The weight captures a potential lack of representation in the observed data. For instance, in our empirical context, we expect that IT systems will more likely be observed when the courier owns a given transportation segment. Thus, instances where there is ownership but IT systems are absent should be rare. The weight compensates for this problem of representation. Thus, the denominator of the formula for the weight is the conditional probability that, given an attribute, the firm will choose ownership. Other things being equal, if IT systems are absent, the conditional probability of ownership should be low, thereby increasing the weight and placing more emphasis on that observation.

We can now use (b4) to estimate (b3). First, we compute the proportion of parcels in the sample that were transported with consolidated ownership of all segments, i.e.,  $Pr(Own(All) = 1)$ . Second, we use a probit model with  $Own(All)$  as the dependent variable and  $x$  as the vector of explanatory variables, which allows us to compute the predicted probability that a shipment with attributes  $x$  will involve ownership of all segments, i.e.,  $Pr(Own(All) = 1 | x)$ . We then plug the computed weight  $\theta$  in the density estimator (2) for the subsample of shipments involving ownership of all segments to estimate the counterfactual density (b4). Weights are computed generically for all ownership patterns by using  $\theta = Pr(Own(\cdot) = 1)/Pr(Own(\cdot) = 1 | x)$  and estimating (b4) for the corresponding subsample where  $Own(\cdot) = 1$ .

Fortunately, we can use an existing model to compute  $Pr(Own(All) = 1 | x)$  and other conditional probabilities involving other ownership patterns for this database. Nickerson et al. (2001) propose a multiple-stage model of governance choice where a key variable belonging to vector  $x$  is the level of investment in idiosyncratic IT used by a courier and embodied in a certain shipment. The model and its rationale are described in Appendix A.

### Appendix C. Carneiro et al. (2003) Model of Density Estimation with Self-Selection: A Brief Description and Comparison to the DiNardo et al. (1996) Method

The Carneiro et al. (2003; henceforth CHH) method extends matching procedures in the treatment effect literature by modifying the LISREL-type framework of structural equations. The methodology is based on the identification of a low-dimensional latent factor structure to control for

unobserved conditioning variables influencing the agents' self-selection into educational training programs. In our case, self-selection is based on firms' decision to send a particular parcel according to each ownership mode.

In the CHH method, unobservables follow a latent factor structure. In particular, the system is identified by linking measurement equations to choice equations through the addition of the latent factor structure. To create the distribution of counterfactual distributions controlling for self-selection, we modify the procedures in Appendices A and B of our paper and follow the steps proposed in CHH. Thus, we construct a low-dimensional latent factor structure linking the organizational equations ( $a_j$ ) to the choice equations (a1), (a2), (a3), and (a4) indicated in Appendix A. Consequently, latent factors are aimed at controlling for unobservable variables that are potentially missing in Equations (a1), (a2), (a3), and (a4). The simultaneous estimation of Equations ( $a_j$ ) and Equations (a1), (a2), (a3), and (a4) is based on the Markov chain Monte Carlo (MCMC) procedure using the Gibbs sampler.

We used the conditions described in §4.2 of CHH to identify latent factors. Note, however, that the CHH study employs a richer dynamic panel structure, which is not present in our study. The identification of latent factors is completed by imposing exclusion restrictions on the factors that can enter in each choice equation (a1), (a2), (a3), and (a4). We tried other schemes, but the results were not substantially affected. We also employed a dimension of 2 for the latent factors; higher dimensions did not affect the probabilities calculated in the probit equations, and made the convergence in the MCMC estimation more difficult. Probably, this was caused by the lack of a dynamic panel structure in our data and our reduced sample size, which did not allow us to set up a more complete factor structure.

We used the BRugs package in R language to write the code and carry out the sampling. The choice equations were estimated using Albert and Chib's (1993) Bayesian approach. Priors in the model are multivariate normal for the ( $a_j$ ) SUR system of equations and the latent factor, using the Wishart density for precision matrices. We assume normal priors and inverse gamma for the variances for the parameters for conditioning variables in the probit model and loading parameters. The estimation is based on a burn-in period of 5,000 iterations and after 20,000 iterations for the recording of Markov chains. We then follow the normal procedure described in Appendix A to estimate the counterfactual densities, now controlling for the potential bias caused by self-selection.

Because the model was estimated using Bayesian methods, we use a common procedure for the Bayesian model selection based on the Bayes factor, which is an alternative to classical hypothesis testing. The Bayes factor is the ratio between the marginal likelihood of the two models under consideration. The general form of this test is given by  $K = p(x | M_1)/p(x | M_2)$ , where  $p(x | M_1)$  and  $p(x | M_2)$  define the likelihood function integrated on the parameters  $x$  (i.e., the marginal likelihood function) for the alternative (1, 2) model specifications. According to Jeffreys (1961), values above 3 represent significant support to the Model 1 over Model 2. Using the marginal likelihoods, it is also possible to construct an asymptotically equivalent likelihood ratio test to compare the models. This construction uses the property of asymptotic equivalence between parameters estimated by maximum likelihood and the

**Table C.1 Comparison of Alternative Models to Assess Potential Self-Selection Bias**

	DiNardo et al. (1996)	Carneiro et al. (2003)
Marginal likelihood	−3957.43	−3950.52
Bayes factor		1.002
Likelihood ratio (LR)		13.82
<i>p</i> -value LR		0.181

posterior distribution estimated by Bayesian procedures (e.g., Schervish 1995).

The Bayes factor of 1.001749 and the likelihood ratio *p*-value equal to 0.181 suggest the absence of significant self-selection effects in our context (Table C.1). Thus, the DiNardo et al. (1996) method is apparently appropriate to estimate the counterfactual densities in our study; self-selection is apparently not a problem. We tried other identification schemes by changing the latent factors entering in each choice equation, and also augmented the dimension of latent factors. Such modifications did not yield significant differences. The probabilities calculated by using the original procedure and by employing the CHH method are very close, and do not affect the construction of counterfactual densities in any significant way. For this reason, we decided to keep the original DiNardo et al. (1996) procedure in our paper.

## Endnotes

<sup>1</sup>For instance, studies have examined the effect of organizational choices on customer satisfaction (Gulati and Nickerson 2008, Poppo and Zenger 1998), transaction costs (Masten et al. 1991), patenting activity (Sampson 2004), and overall project profitability (Mayer and Nickerson 2005). See also Armour and Teece (1980), Silverman (1999), Silverman et al. (1997), Heide and John (1990), and Stump and Heide (1996).

<sup>2</sup>We are not considering here a distinct form of deviation related to “design error”: the extent to which product attributes, even if correctly present in the product or service, fail to meet the demands of customers. For instance, a courier may design and advertise a cheaper delivery service in one week, although in reality most customers appreciate very express deliveries. Because our focus is on deviations that occur due to failure or quality problems in production processes, we leave an expanded discussion for this alternative kind of deviation for future research. We thank an anonymous referee for raising this point.

<sup>3</sup>As Vromans et al. (2006, p. 648) highlight in their paper on railway services, “the predictability of the arrival times [of trains] is a big factor in deciding to use rail or road transport, both for passengers and for cargo,” and “punctuality is probably the most widely used reliability measure in practice [for railways], both in The Netherlands and abroad” (p. 649; also see Harris and Winston 1983).

<sup>4</sup>The term parcel is used to describe either a package or document.

<sup>5</sup>Among 16 firms interviewed, only one firm, Fukuyama Transporting Co. Ltd., fully internalizes all pickup/delivery trucking operations. Similarly, only a few firms are integrated into international air transport out of Japan. Whereas Federal Express, DHL, and UPS-Yamato can be classified as integrated, all other freight forwarders contract for international

air carriage. Many of the firms such as Airborne Express, BAX Global, Emery Air Freight, and TNT Express Worldwide do integrate into international air transport between some foreign cities or in the United States, but have not integrated air transport into or out of Japan.

<sup>6</sup>In contrast, most other transportation resources such as aircraft, vehicles, parcel handling facilities, and sorting equipment are comparatively redeployable, and thus are unlikely to be critical elements that induce an advantage of ownership over contracting in the provision of highly reliable delivery.

<sup>7</sup>Parcel data collected by couriers was either self-reported, recorded directly on test parcels sent by researchers, or reported by shippers who assisted in IPTP’s research. Information about the ownership pattern used by couriers in each transportation segment and city pair was collected through interviews.

<sup>8</sup>Alternatively, we could have examined combinations of organizational patterns along the chain. For instance, we could have observed the performance of parcels transported through ownership of domestic trucking, ownership of air transportation, and nonownership of foreign trucking. Unfortunately, however, we have few instances of some combinations in our data. Thus, we have zero instances of the pattern involving ownership of air transportation and nonownership of domestic and foreign trucking, 20 instances of the pattern involving nonownership of domestic trucking and ownership of air transportation and foreign trucking, etc. Thus, we decided instead to observe the effect of ownership in a “marginal” fashion; i.e., we assess what would happen if the firm controlled a particular segment, all else being constant.

<sup>9</sup>However, if we use the original values of the ownership variables, the qualitative inference of our results is identical.

<sup>10</sup>The formula specifies  $h = 0.9 \frac{m}{N^{1/5}}$ , where  $m = \min(\sigma, \text{interquartile range}/1.349)$ ,  $\sigma$  is the standard deviation, and  $N$  is the number of observations.

<sup>11</sup>The original database contains information on 995 parcels. We had to reduce the number of observations in our analyses due to missing values for some variables.

<sup>12</sup>The notable exception comes from Michael (2000), who focused on the effects of the diffused, decentralized nature of franchising on the quality of product and service offerings in the restaurant and hotel industries, respectively.

<sup>13</sup>Interestingly, this issue raises another conjecture: ownership can possibly be associated with lower variability in *governance costs*. Improved coordination and monitoring in hierarchies may allow for a better control of expenses to manage sequential stages in the value chain. By contrast, contracting tends to be extremely susceptible to unforeseen contingencies, possibly causing a very volatile flow of expenses. This can be easily incorporated in our model when one considers that governance cost is a variable that influences the economic performance of products or services. This conjecture also reaffirms our claim that attention to performance variability can create new avenues of research that can increase our understanding about the net benefits provided by ownership or other governance modes.

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