

Retailer-Supplier Coordination of Pricing and Delivery Ratings Availability Decisions in Online Marketplaces

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Abstract: Businesses selling in online marketplaces often enhance their offerings with short delivery times, but short delivery times typically result in low delivery-time conformance—the probability of on-time delivery, often published in the form of delivery-time ratings. As a result, short delivery times may simultaneously enhance and undermine the perceived value of online offerings. Marketplace operators can moderate this trade-off between delivery time and delivery-time conformance by making delivery-time ratings available or not. We (i) characterize the conditions for the emergence of the trade-off, (ii) identify the mechanisms that may allow managers to preempt the trade-off, and (iii) outline the conditions under which it is profitable for online retailers to solicit and publish delivery-time ratings. We model and compare alternative scenarios for the supply chain of a retailer and a supplier that offer a product in an online marketplace and determine prices and promised delivery times. We develop analytic models and support them with data provided by the Cainiao’s logistic network. Differences of outcomes across scenarios reveal that the aforementioned trade-off can be preempted by simultaneously making delivery-time ratings available and coordinating the prices and promised delivery times. Disclosure of ratings can reduce delivery times but is profitable only if the disclosure increases system-wide value. Confirming this finding, analyses of Cainiao’s data indicate that the availability of delivery-time ratings can reduce the average promised delivery time by 3.9 hours (or 7.4%). Several extensions show that our results hold for different contexts, including both drop-shipping and retailer-managed fulfillment models. In conclusion, our results suggest when and how supply chains in online marketplaces can use pricing to make the offering of shorter delivery times a dominant strategy.

Keywords: supply chain, online markets, delivery time, online ratings.

1 Introduction

As Internet penetration advances, an increasing number of products and services are available in online marketplaces. This proliferation of offerings increases search costs for consumers and leads them to rely on ratings from other customers to infer the attributes of offerings, such as quality, delivery time, and after-sale service. In a survey of 18,430 online shoppers across more than 50 countries (KPMG International 2017), 43% of those shoppers reported considering delivery service as the most important attribute of online offerings. The survey also revealed that delivery time is by far the most influential aspect of delivery service. Another survey that focused on the different aspects of delivery service (Carollo 2018) found that 74% of U.S. consumers are willing to pay more for fast delivery and that 75% care about on-time delivery. The overall rate of on-time delivery is hereafter referred to as *delivery-time conformance*.

Retailers operating in online marketplaces can communicate the speed of deliveries to consumers by posting promised delivery times on the webpages that showcase their products. Like-

wise, online marketplaces can communicate the degree of delivery-time conformance by posting consumer ratings of delivery times (hereafter referred to as *delivery-time ratings*). As illustrated by the top row of Figure 1, a number of online marketplaces implement subdivided rating systems (Wang et al. 2020) to allow customers to rate delivery times, together with product quality, and customer service quality. While a few systems (e.g., Sitejabber) also encourage customers to rate value, returns, etc., most subdivided rating systems include only delivery time, product quality, and customer service quality (e.g., Just Eat and Menulog). Other online marketplaces implement aggregated product ratings, which do not allow for separate ratings for delivery-time and focus on product quality only. Some of these aggregated review systems however do allow customers to provide feedback on different aspects of the purchase experience through textual reviews; see, for example, Amazon and iHerb in Figure 1. Making delivery-time ratings available is appealing to online retailers because the information conveyed by such ratings can refine consumer expectations of actual delivery time and delivery-time conformance (Esper et al. 2003), thus enhancing the appeal of offerings (see also Chen, Hong and Liu 2018).

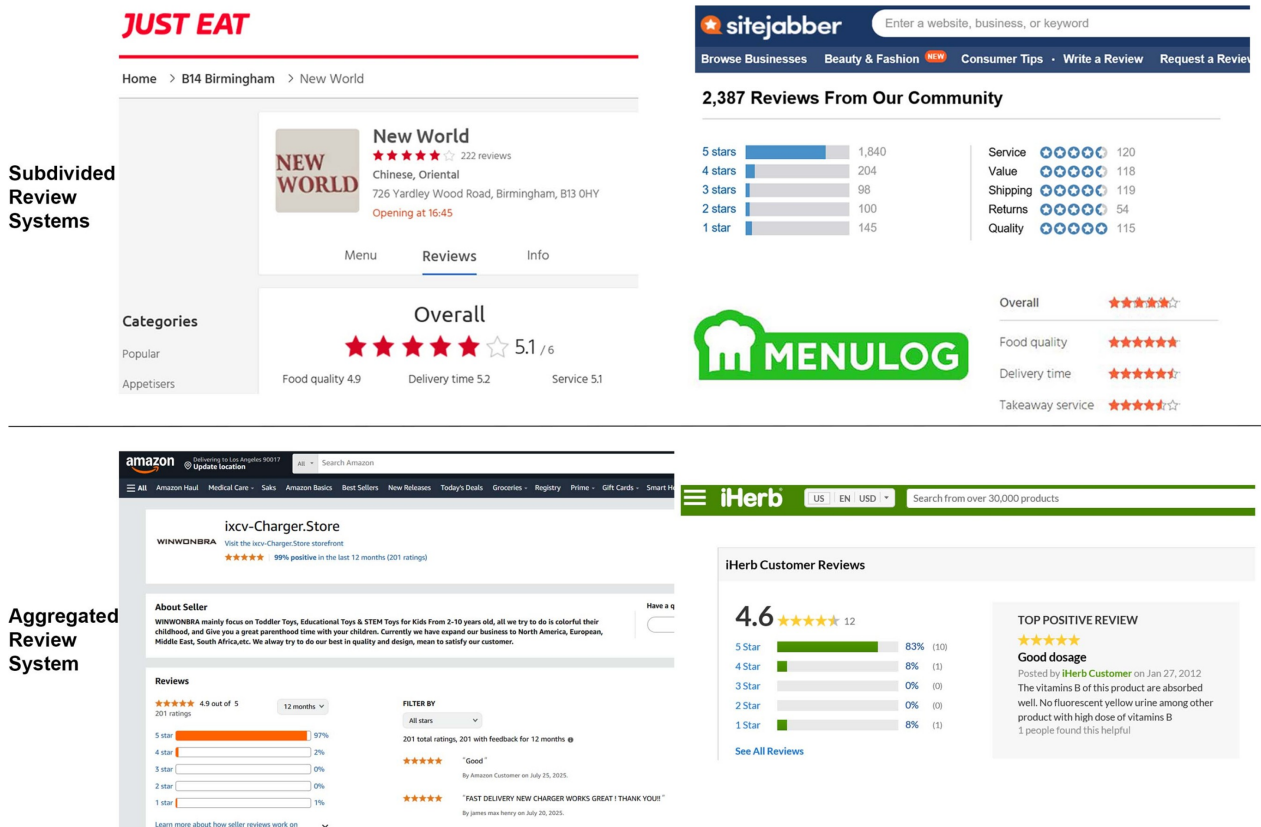


Figure 1: Examples of subdivided and aggregated review systems.

Yet, the availability of delivery-time ratings is not problem-free. As reported by managers of delivery service providers (see Cosgrove 2019), online retailers and their suppliers may promise short delivery times to attract consumers, but short promised delivery times are riskier than long ones. The probability of late deliveries increases with shortening delivery times and delivery-time ratings reveal this information, otherwise unknown, to consumers. Hence, when delivery-time ratings are available, online retailers and their suppliers face a problematic trade-off between promising shorter delivery times and risking lower delivery-time ratings.

Previous research has addressed some special cases of a similar problem that arises in the

context of manufacturing, where firms offer delivery time guarantees to buyers of their products but may fail to deliver on time (Nozari and Alavi 2026). For example, Chatterjee, Slotnick and Sobel (2002) propose a profit optimizing decision rule for promised delivery times in a B2B setting where late deliveries are penalized and prices are fixed. Similarly, Shang and Liu (2011) model the delivery time decision of a retailer supplying products at a fixed price to buyers who care about both delivery time and delivery-time conformance. They analyze the trade-off between delivery time and conformance to find the optimal promised delivery time. The relevant research that endogenizes prices, on the other hand, tends to account for the benefits of short delivery-times but ignores delivery-time conformance (e.g., So 2000, Liu, Parlar and Zhu 2007). Boyaci and Ray (2006) may be the first to allow consumer demand to directly depend on prices, promised delivery time, and delivery-time conformance simultaneously. The authors, however, focus on the role of investments in service capacity instead of the availability of delivery performance information. Closest to this paper is the work of Leng et al. (2024), who account for the trade-off between promised-delivery times and delivery-time conformance when modeling a single firm that simultaneously decides on prices, promised delivery-time, and the investment in the quality of delivery conformance information available to consumers. These studies typically assume that both pricing and delivery-time decisions are made by managers inside a single firm. We note, however, that the dominant logistic model for online retailers is drop-shipping (Li et al. 2016). Under the drop-shipping model, retail prices are set by online retailers but their promised delivery times are determined by the suppliers.

In this paper, we investigate the optimal delivery-time rating availability and retail pricing decisions for a two-echelon supply chain, in which a supplier leads by determining the wholesale price and the promised delivery time, and an online retailer follows by deciding on the retail price. Yet, because the retailer-managed fulfillment model (Li et al. 2016) is also common in practice, we replicate our analyses for a setting in which fulfillment is handled by the retailer instead of the supplier. We propose game-theoretic models to (i) characterize conditions for the emergence of the trade-off between delivery time and delivery-time conformance, (ii) assess whether a combination of delivery-time rating availability and suitable pricing policies can preempt the trade-off, and (iii) outline conditions under which it is profitable for the online retailer to solicit and publish delivery-time ratings. We begin by developing a consumer utility function that depends on product quality, promised delivery time, and delivery-time ratings. Like Shang and Liu (2011) and Leng et al. (2024), we model the effect of delivery time on delivery-time conformance, hence allowing for their trade-off. We then analyze the utility function to derive expected demand functions. To empirically validate the model development and its implications in a real online market setting, we analyze data from Tmall, a leading marketplace in China that implements subdivided reviews (see Figure I in Online Appendix I). In agreement with this institutional context, our model assumes that consumers enjoy free shipping and rate the delivery service according to the difference between the actual and promised delivery times. We use a general shipping cost function of promised delivery time.

Similar to previous studies that address the trade-off between delivery times and delivery-time conformance in the context of a single firm, our analyses indicate that, in the supplier-retailer supply chain, the optimal promised delivery time is decreasing in the consumer sensitivity to promised delivery time. Unlike the previous studies, we find that the optimal promised delivery time is also decreasing in the sensitivity to delivery-time conformance. To explain this, we analyze alternative scenarios with and without delivery-time ratings and with and without

endogenous pricing. We show that the optimal promised delivery time is decreasing in the sensitivity to delivery-time conformance only when delivery-time ratings are available and pricing is endogenous. It is the combination of delivery-time ratings availability and endogenous pricing that makes shorter promised delivery times unequivocally profitable, regardless of whether the retailer or the supplier decides the promised delivery time. In both drop-shipping and retailer fulfillment models with endogenous pricing, the disclosure of delivery-time ratings results in shorter optimal promised delivery times and higher shipping costs, but not necessarily higher prices. If delivery-time ratings are available, shorter promised delivery times induce the supply chain to increase the wholesale price but whether the retail price increases or not depends on how elastic the marginal shipping cost is with respect to the promised delivery time. If pricing is endogenous and delivery-time rating availability increases system-wide value (i.e., the sum of consumers' total utility and the supply chain's shipping cost), both the supplier and the retailer benefit from disclosing the ratings. Our empirical analyses support our predictions by showing that, when delivery-time ratings are available at Tmall, the average promised delivery time is 3.91 hours shorter, or 7.40% smaller, than the sample average of 52.95 hours. Additional empirical results are also in line with relevant conclusions drawn from our theoretical analysis.

Our findings make a twofold contribution to the aforementioned literature that models delivery time decisions when consumers care about both promised delivery time and delivery-time conformance. First, the findings generalize previous results concerned with a single firm to the supply chain contexts of drop-shipping and retailer-managed fulfillment. Second, the findings explain differences in results across previous studies and identify the modeling decisions that cause such differences. More broadly, this paper contributes to previous research on pricing in the presence of consumer ratings or other relevant online information. For example, Dewan, Freimer and Jiang (2007) investigate a setting in which retailers decide on their prices when consumers use online information on inventory status as a proxy for delivery time. Kuksov and Xie (2010) study a firm's optimal pricing and fulfillment decisions when consumers base their expectations on consumer ratings that are influenced by frills such as delivery, after-sale service, etc. Sun (2012) constructs a two-period model to study consumer purchase behaviors in the presence of product quality reviews and to find the optimal retail prices that maximize a seller's profit. Feng, Li and Zhang (2019) analyze a dynamic game to explore how a firm may use its pricing to influence online product reviews and to respond to online word of mouth. We contribute to this body of literature by formalizing the important interaction between pricing and delivery time decisions.

The remainder of this paper is organized as follows. We describe the institutional context and data in Section 2 and report the data cleaning process and statistics in Appendix A. Then, in Section 3, we develop and analyze consumer utility functions to derive aggregate demand functions. We then present our main results for the drop-shipping fulfillment model in Section 4 and replicate them for the retailer-fulfillment case in Appendix B. We further explore the generalizability of the results by analyzing a scenario with two retailers in Appendix C and a scenario with bargaining in Appendix D. We derive two testable implications of our models in Appendix E and present supporting empirical evidence in Section 5. Section 6 summarizes the main theoretical and practical implications of our results. Online Appendix I describes the raw data. Proofs appear in Online Appendix II and robustness tests appear in Online Appendix III.

2 Institutional Context, Data, and Model Foundations

2.1 Setting and Data

We next describe the institutional context and the respective data that inform and support our analyses. Specifically, we consider a supplier-retailer supply chain in which the retailer sells the supplier’s product through a digital retailing platform. The supply chain thus implements the drop-shipping business model, in which the retailer sets the retail price and the supplier determines both the wholesale price and the promised delivery time. For the actual delivery time to reflect the promised delivery time, the supplier sets the delivery speed and incurs a cost proportional to the speed. This general setup describes the operations of the Tmall platform, a major marketplace operated by Alibaba Group—the world’s largest e-commerce company. At Tmall, when a retailer sells a product to a consumer, the supplier can directly ship the product to the consumer using the services of logistics companies in the Cainiao Network. The Cainiao Network is a consortium formed by the Alibaba Group and several leading logistics firms that, altogether, handle approximately 70% of all the online orders in China (Deagon 2018). These logistics service providers offer several standardized shipping options, including Cainiao Super Economy, Cainiao Expedited Standard, and Cainiao Heavy Parcel Line⁴, each of which involves a different delivery speed and fee⁵. Cainiao helps suppliers choose among these logistics service providers by collecting and sharing information from all affiliated logistics firms⁶. These firms report order details, delivery status, and user feedback to Cainiao with an aim to provide high quality service to both suppliers and consumers.

Our dataset includes information regarding almost 160 million orders handled by a sample of 527 supplier-retailer pairs operating on Tmall’s platform. The data include dates, prices, quantities, promised delivery speed, and consumer ratings for individual transactions occurring between January 1st and July 31st, 2017 (see Appendix A and Online Appendix I for details). We use this dataset for two purposes. First, we use the data to inform modeling decisions and to ensure that our theoretic model is realistic and sound. Second, we use the data to empirically test the predictions made by the theoretic model. We note that the data reflects the effects of factors that fall outside of the scope of our problem of interest, such as the unobserved physical distances between suppliers and consumers and unobserved differences across products. The effects of these extraneous factors could be confounded with the effects of our interest and hence we need to take them into consideration. We do so in two different ways.

First, we condition out the extraneous factors by selecting a subsample within which the extraneous factors are constant or absent. This approach allows us to analyze the data without having to rely on restrictive distributional assumptions. To control for unobserved distances between suppliers and consumers, we drop observations in which the shipments originate at a city different from the city of the final destination. Likewise, we only consider the orders that were fulfilled by the logistic firms affiliated with the Cainiao Network to control for unobserved characteristics of different fulfillment services. We note that, at Tmall, orders are shipped by suppliers rather than by retailers. Hence, each order contains items from one supplier only and the supplier can set the promised delivery time independently. Even if the Cainiao Network pools some orders, it does so after all orders have been placed and promised delivery times have been set (Chen et al. 2024). Nonetheless, a supplier could source different products from different origins and thus the delivery time of one item may depend on the delivery time of another item.

Because this could induce noise in the measurement of promised delivery time, we drop a small percentage of orders with multiple items and analyze orders that involve a single product only. In addition, we drop observations with missing promised delivery time and ratings. We verify that our final sample is representative by confirming that these filtering steps preserve the average values of product prices, promised delivery time, actual delivery time, and delivery-time ratings, as reported in Table A of Appendix A. The final sample thus consists of 4,741,544 observations (about 55% of all complete observations) that correspond to 277 supplier-retailer pairs and 14,459 distinct items. Descriptive statistics appear in Table B of Appendix A.

Second, we estimate econometric models that explicitly control for extraneous factors using statistical controls. This approach allows us to account for unobserved heterogeneity and other unobserved factors. To control for unobserved supplier-retailer characteristics, such as their ratings at alternative platforms, we use supplier-retailer-specific fixed effects. To control for unobserved product characteristics, such as perishability, we use product-specific fixed effects.

2.2 Model Foundations

We next define our model primitives and use the data to support them. Before placing an order, each consumer can learn about the products and delivery services offered by suppliers to infer the utility associated with the offerings. We use v , t , and t_c to denote the expected product quality, the promised delivery time, and the delivery-time conformance, respectively. We then follow Shang and Liu (2011) to specify the consumer expected utility of buying one unit of an offering at price p as

$$U \equiv v - p - \gamma t + \alpha t_c, \quad (1)$$

where γ denotes the expected utility loss from waiting an additional unit of time and $\alpha > 0$ represents the unit effect of expected delivery time conformance on expected utility. As shown later in Section 3, delivery-time conformance t_c is a function of promised delivery time t . Therefore, the utility model in (1) parallels the model of Shang and Liu (2011), who specified the quality of service as a function of promised delivery time. Later, we use this characterization to construct consumer expectations both when delivery-time ratings are available and when they are not. We next discuss how we model the elements of the utility function in more detail.

To model the expected product quality v , we follow Chen and Xie (2008) and Kwark, Chen and Raghunathan (2014) in defining it as a convex combination of the consumer’s own quality assessment q and the average rating on product quality q_r , where the subscript r stands for “rating.” That is, $v = \phi q + (1 - \phi)q_r$, where $\phi \in (0, 1)$ and $(1 - \phi)$ denote the weights on the two information components. The parameter ϕ weighs the relative precision of these two information sources and could depend on, for example, how familiar consumers are with the product or on how likely consumers are to search for additional information outside of the retailer’s website. When product-quality ratings are available, consumers can observe the average product-quality rating q_r before they make their purchase decisions. This means that the value of q_r is given. In contrast, q is the realization of a random variable Q that may differ across consumers because the degree of fit between the product attributes and consumer needs is heterogeneous (Kwark et al. 2014).

As in previous work (see, for example, Kwark et al. 2014, Chen, Guo and Huang 2022, Ma, Li and Kong 2024), the consumer-specific, product quality assessment Q is uniformly distributed over $[0, \bar{q}]$, where the single upper bar denotes an upper bound. That is, the probability density

function (p.d.f.) $g(Q)$ is $g(Q) = 1/\bar{q}$, for $Q \in [0, \bar{q}]$. If product-quality ratings are available, then a consumer's maximum expected product utility is $\bar{v} \equiv \phi\bar{q} + (1 - \phi)q_r$. Otherwise, if the product-quality rating is not available, then the consumer's expected product utility v depends only on her own assessment q , i.e., $v = q$, and her maximum expected product quality is $\bar{q}$. No assumption on how $\bar{v}$, $\bar{q}$, and q_r compare to each other is required in either case. Hence, our results do not depend on any particular specification of v .

We define p as the retail price set by the retailer excluding shipping fees. The consumer utility specification in (1) does not include a shipping fee, because Tmall shoppers seldom pay shipping fees. Most of Tmall suppliers provide free shipping within China⁷. More generally, domestic shoppers almost always enjoy the free shipping service from Cainiao-affiliated retailers. For example, during the "Double 11" promotional period of year 2021, approximately 98% of all parcels from all retailers in China were delivered under the free shipping service policy, as reported by the Global Times⁸. In Tmall's case, almost all suppliers offer free shipping service as the default and the only shipping option. In these cases, the shipping cost is absorbed by suppliers.

We treat the promised delivery time t as a supplier's decision that determines the actual time a customer has to wait for the order to be delivered, hereafter referred to as the delivery wait or the actual delivery time T_a , where the subscript a stands for "actual". As mentioned above, in Tmall's case, the logistics companies members of the Cainiao Network offer standardized shipping options for suppliers to choose from. Regardless of whether a supplier intends a short or long delivery time, the supplier can choose a logistics service provider with a proper shipping option and pays the corresponding shipping fee. Thus, because each supplier is able to choose among all the given logistics service options in the Cainiao Network, we consider the promised delivery time as a supplier's decision variable.

We expect the actual delivery time T_a to increase with the promised delivery time t , and the average actual time to be shorter than the average promised time. In our institutional context, suppliers promise same-day, next-day, and two-day delivery before 9:00pm for orders that were placed before 11:00am. Analogous delivery times are offered for orders placed before midnight (see Online Appendix I for details). The promised delivery deadlines are reflected in the distribution of T_a , which, as depicted in the left-most plot in Figure 2, exhibits modes right below 8, 20, and 44 hours. We accordingly let $T_a = \beta t + \varepsilon$, where $0 < \beta < 1$ and ε is a uniformly-distributed random variable in the range $[0, \bar{\varepsilon}]$ with upper bound $\bar{\varepsilon}$ and p.d.f. $f(\varepsilon) = 1/\bar{\varepsilon}$. This definition of T_a holds for different combinations of values for β and $\bar{\varepsilon}$. For example, we can let $\hat{\beta} = \text{median}(T_a - t)$, where the median is taken across transactions, and define $\hat{\varepsilon} = T_a - \hat{\beta}t$. If $\hat{F}_{\hat{\varepsilon}}(\cdot)$ represents the empirical distribution of $\hat{\varepsilon}$, then $\varepsilon = \hat{F}_{\hat{\varepsilon}}(T_a - \hat{\beta}t)$ is uniformly distributed on $[0, 1]$. The middle plot in Figure 2 depicts the distribution of $\hat{\varepsilon}$, which may deviate from normality because of the factors such as differences over days of the week, across products, and across the technologies of different regional operators (Yao, Dresner and Zhu 2019). The right-most plot depicts the nearly-uniform distribution of $\hat{F}_{\hat{\varepsilon}}(T_a - \hat{\beta}t)$ for $\hat{\beta} = \text{median}(T_a - t) = 0.95$ and $\bar{\varepsilon} = 1$.

While the exact value $\bar{\varepsilon}$ may be unknown to consumers, they implicitly estimate it when forming expectations of actual delivery times and delivery time conformance. Making information about expected waiting times available to consumers can significantly reduce an overestimation of actual waiting times and their variance (Esper et al. 2003, Kumar, Kalwani, and Dada 1997). Hence, making delivery-time ratings available can reduce the expected delivery times as well as their expected variance, both of which are proportional to $\bar{\varepsilon}$. That is, the maximum expected

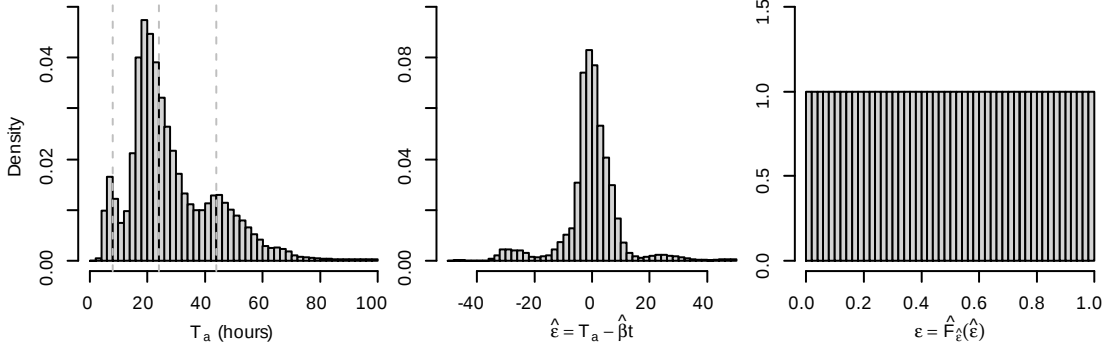


Figure 2: Distributions of delivery times for $\bar{\varepsilon} = 1$ and $\hat{\beta} = 0.95$.

delivery time when delivery-time ratings are available, $\bar{\varepsilon}^A$, is smaller than its counterpart when delivery-time ratings are not available, $\bar{\varepsilon}^N$; i.e., $\bar{\varepsilon}^A \leq \bar{\varepsilon}^N$.

Consumer sensitivity to the delivery time, represented by the parameter γ , satisfies $\alpha(1-\beta) < \bar{\varepsilon}\gamma$ and thus, the expected delivery utility is decreasing in t . This implication cannot be tested directly because consumer utility is not observable. However, we can support it by showing that prices paid, and thus willingness to pay, decline with t . Noting that prices depend on both unobserved product features (such as quality and size) and unobserved supplier features (such as economies of scale), we estimate the relationship between promised delivery time t and prices conditional on item and supplier fixed effects. To allow for nonlinearity, we consider cubic Truncated Power Function (TPF) splines but we note that delivery delay exhibits a skewed distribution with the vast majority of the observations lumped near zero. This imbalance across the support of the data often leads cubic TPF splines to exhibit bad tail behavior and therefore we instead rely on natural cubic splines (Wood 2017). We then use the estimated regression equation to predict and plot prices for the observed values of t . Here, we set the values of the fixed effects to 0 so that the prices predicted are centered at 0 and represent the deviation of prices from their item and supplier averages. The results, given in Figure 3, indicate that prices paid, and thus utility, decline with promised delivery time.

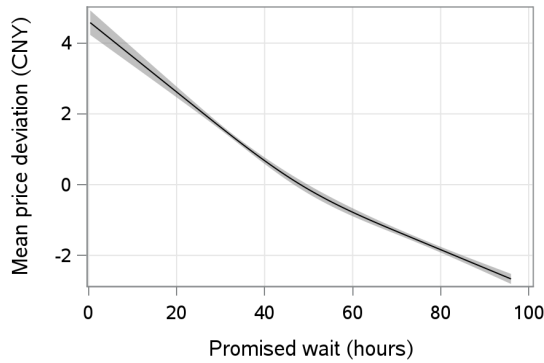


Figure 3: Mean deviation of prices from their item and supplier averages as function of promised delivery time. The gray envelope represents the 95% confidence interval of the mean.

Finally, we model delivery-time conformance t_c . We start by noting that the supplier promises $t \leq \bar{t}_a \equiv \max T_a = \beta t + \bar{\varepsilon}$, where $\bar{t}_a$ is the longest actual delivery time. This implies that $(1-\beta)t \leq \bar{\varepsilon}$ and the actual delivery-time conformance is given by the actual probability of timely

delivery:

$$t_c = \Pr(T_a \leq t) = \Pr(\varepsilon \leq (1 - \beta)t) = (1 - \beta)t/\bar{\varepsilon}. \quad (2)$$

This expression shows that t_c is increasing in t because longer promised delivery times reduce the probability that a delivery arrives late. Consumers may infer the value of t_c by first constructing an estimate of $\bar{\varepsilon}$ through either of two possible approaches, depending on whether delivery-time ratings are available or not, as discussed below.

3 Consumer Demand

We propose a basic model of consumer expectations of conformance for the scenarios with and without delivery-time ratings. Then, we derive aggregate demand functions in terms of the retailer’s decision variable p and the supplier’s decision variable t .

3.1 Consumer Expectations when Delivery-Time Ratings Are Available

When average delivery-time ratings t_r are allowed, consumers rate products and delivery times (e.g., on a scale of 1 to 5) after transactions are completed. The retailer aggregates consumer ratings for each product as an average over a rolling twelve-month window and updates the average rating displayed on the product’s page. Consumers may then use these posted averages to infer the longest possible delivery delay $\bar{\varepsilon}$ and the delivery-time conformance t_c of the supplier. These variables are related through consumer satisfaction as follows.

Published delivery-time ratings reflect the satisfaction of individual consumers and therefore depend on the conformance of individual deliveries. Industry studies indicate that ratings measure both the actual delivery time and the delivery time conformance. For example, Bringg (2021) reports that 57% of customers will not return to a retailer after three late deliveries and, in today’s digital era, those customer complaints may quickly turn into negative reviews online. Therefore, Bringg concludes that measuring on time delivery rates reveals the effectiveness of a delivery service and can thus help online firms improve rates of customer satisfaction. This implies that ratings measure the conformance of delivery time. MetricHQ (2025) and OptimoRoute (2025) report similar insights.

Accordingly, we let the difference $T_a - t$ represent consumer satisfaction, which determines the delivery-time rating T_r (here, the subscript r again stands for “rating”). Naturally, if $T_a \leq t$, then the consumer should be satisfied with the actual delivery time and thus grant a high rating. Otherwise, if $T_a > t$, then the consumer is very likely to be displeased and provide a low rating.

The effect of conformance on satisfaction is, however, not linear. Consumer satisfaction is subject to a negativity bias and a ceiling effect (Eisenbeiss et al. 2014), such that the benefits of exceeding consumer expectations are very limited and even negligible compared to the effects of not meeting them (Dixon, Freeman and Toman 2010). We show that this holds in our institutional context by plotting the delivery ratings in the Cainiao dataset as a regression function of the delivery delay $T_a - t$. To control for unobserved items and supplier factors, we include item and supplier fixed effects. To allow the relationship to be nonlinear, we use a natural spline regression model. Altogether, the fixed effects and spline terms explain $R^2 = 0.987$ of the total variation of ratings. The regression line, plotted in Figure 4, shows that the ratings decline when $T_a > t$ but are nearly constant when $T_a \leq t$. We therefore model both negativity and ceiling effects of satisfaction by defining consumer dissatisfaction with delivery-time conformance at the individual

level as $\min\{0, T_a - t\}$. Consumer satisfaction is thus given by the negative of dissatisfaction, or $\mu \equiv -\min\{0, T_a - t\} = \max\{0, t - T_a\} = \max\{0, (1 - \beta)t - \varepsilon\}$. We then construct the rating function as $T_r = \underline{t}_r + k\mu$, where $\underline{t}_r \geq 0$ denotes the minimum rating and k represents the unit impact of consumer satisfaction on the delivery-time ratings. This rating function indicates that a consumer with a higher satisfaction level would provide a higher rating score above the minimum rating $\underline{t}_r$ (i.e., the lowest delivery-time rating for the logistics service).

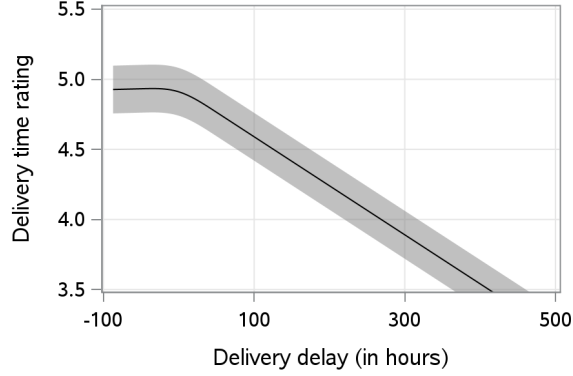


Figure 4: Average delivery-time rating as function of delivery delay. The grey envelope represents the 95% confidence interval of the mean.

Next, we express the average delivery-time rating as

$$t_r = E(T_r) = \underline{t}_r + kE(\mu) = \underline{t}_r + k \int_0^{(1-\beta)t} [(1-\beta)t - \varepsilon] f(\varepsilon) d\varepsilon = \underline{t}_r + \frac{k[(1-\beta)t]^2}{2\bar{\varepsilon}}, \quad (3)$$

which indicates that the average delivery-time rating is decreasing in the longest possible delivery delay $\bar{\varepsilon}$ and increasing in the promised delivery time t . Shorter (longer) promised delivery times lead to lower (higher) ratings because they lead to lower (higher) conformance *ceteris paribus*. Thus, delivery-time ratings capture the effect of delivery time on delivery-time conformance.

Given the useful information contained in the published average delivery-time ratings t_r , consumers may use them to derive a rough estimate of the longest possible delay $\bar{\varepsilon}$. According to (3), such consumer estimate should approximate

$$\bar{\varepsilon}^{\mathcal{A}} \equiv \frac{k[(1-\beta)t]^2}{2(t_r - \underline{t}_r)}, \quad (4)$$

where the superscript $\mathcal{A}$ denotes the availability of delivery-time ratings (we conversely use the superscript $\mathcal{N}$ to denote the unavailability of ratings). Consumers can use their estimate of $\bar{\varepsilon}^{\mathcal{A}}$ or the published ratings directly to derive a rough estimate of the conformance of the supplier as an approximation to the expected conformance given by

$$t_c^{\mathcal{A}} \equiv \Pr(\varepsilon \leq (1-\beta)t | t_r \text{ is available}) = \frac{(1-\beta)t}{\bar{\varepsilon}^{\mathcal{A}}} = \frac{2(t_r - \underline{t}_r)}{k(1-\beta)t}. \quad (5)$$

The expression in (5) reveals that a high average delivery-time rating signals a high likelihood of consumers receiving their ordered products within the promised delivery time.

3.2 Consumer Expectations when Delivery-Time Ratings Are Unavailable

When average delivery-time ratings are not available, consumers can only use promised delivery times and their experience to infer the longest possible delay $\bar{\varepsilon}$ and the expected delivery-time conformance t_c . The lack of additional delivery information leads consumers to expect a lower delivery-time conformance and longer delivery times than when the delivery information is available (Esper et al. 2003). This occurs because (i) trust is less likely without ratings (Rice 2012) and trust is associated with higher expectations, or (ii) the lack of information leads consumers to consider all (including the worst) possible outcomes. The worst possible expected outcome is associated with the longest possible delay, $\bar{\varepsilon}^N$, which consumers can infer from their experiences. As a result, consumers assign the largest possible value of $\bar{\varepsilon}$ to $\bar{\varepsilon}^N$.

It follows from (2) that consumers may infer the delivery-time conformance of a retailer or supplier to be close to the expected value given by

$$t_c^N \equiv \Pr(\varepsilon \leq (1 - \beta)t | t_r \text{ is not available}) = \frac{(1 - \beta)t}{\bar{\varepsilon}^N}, \quad (6)$$

which implies that $t_c^N < t_c^A$ and may thus explain the empirical findings of Esper, Jensen, Turnipseed and Burton (2003).

3.3 Aggregate Demand Functions

We use our individual-level utility specification to derive aggregate demand functions. Without loss of generality, we let the utility of the outside good be zero. A consumer decides to buy a product if $U \geq 0$, which implies that the consumer's assessment of product quality must satisfy

$$q \geq \begin{cases} \underline{q}^A \equiv \frac{p}{\phi} - \frac{2\alpha(t_r - \underline{t}_r)}{\phi k(1 - \beta)t} - \frac{(1 - \phi)q_r - \gamma t}{\phi}, & \text{if } t_r \text{ is available,} \\ \underline{q}^N \equiv \frac{p}{\phi} - \frac{\alpha(1 - \beta)t}{\phi \bar{\varepsilon}^N} - \frac{(1 - \phi)q_r - \gamma t}{\phi}, & \text{if } t_r \text{ is not available,} \end{cases} \quad (7)$$

where $\underline{q}^A < \underline{q}^N$. Otherwise, the consumer does not buy.

Using (7), we calculate the aggregate demand as

$$D = \begin{cases} D^A \equiv M \int_{\underline{q}^A}^{\bar{q}} g(q) dq = M \frac{\bar{q} - \underline{q}^A}{\bar{q}}, & \text{if } t_r \text{ is available,} \\ D^N \equiv M \int_{\underline{q}^N}^{\bar{q}} g(q) dq = M \frac{\bar{q} - \underline{q}^N}{\bar{q}}, & \text{if } t_r \text{ is not available,} \end{cases} \quad (8)$$

where M denotes the market size (i.e., the total number of potential consumers). We learn from (8) that $D^A > D^N$, because the availability of the delivery-time ratings can help reduce consumer estimates of delivery time and increase estimates of delivery-time conformance.

Substituting (7) into (8) and using $\bar{v} \equiv \phi \bar{q} + (1 - \phi)q_r$, we obtain the aggregate demand as

$$D = \begin{cases} D^A = \frac{M}{\phi \bar{q}} \left[\bar{v} - p - \gamma t + \frac{2\alpha(t_r - \underline{t}_r)}{k(1 - \beta)t} \right], & \text{if } t_r \text{ is available,} \\ D^N = \frac{M}{\phi \bar{q}} \left[\bar{v} - p - \gamma t + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^N} \right], & \text{if } t_r \text{ is not available.} \end{cases} \quad (9)$$

Using (9), we can find $\partial D^A / \partial p < 0$ and $\partial D^N / \partial p < 0$, which implies that an increase in the

retail price can invariably reduce consumer demand regardless of whether the ratings information is available or not.

The equations in (9) complete our model specification. For the ease of reference, we provide a list of symbols used in Table 1. As defined previously, superscripts $\mathcal{A}$ and $\mathcal{N}$ label variables for the scenarios with and without available ratings, respectively. We also use the superscript $\mathcal{F}$ to qualify variables of scenarios in which prices are “fixed” or exogenous. The superscripts $\mathcal{AN}$ and $\mathcal{NB}$ identify variables in the setting of two different retailers and the setting of Nash bargaining, respectively. In addition, the tilde “ $\sim$ ” denotes the retailer fulfillment scenario, the single overbar “ $\bar{\cdot}$ ” denotes the upper bound of its argument $\cdot$, and the single underbar “ $\underline{\cdot}$ ” denotes the lower bound of $\cdot$. These mathematical expressions apply to all symbols in Table 1.

Table 1: List of symbols used.

Parameter	Description
M	Market size
c, s	Unit acquisition cost of supplier, unit delivery cost
U, u	Expected consumer total utility, expected delivery utility
$v, \bar{v}$	Expected product quality, upper bound on expected product quality
Q, q	Random variable and realized value of consumer’s own product quality assessment
$\bar{q}, \underline{q}$	Upper bound and lower bound on own product quality assessment
$q_r, \bar{t}_r$	Average product-quality rating, average delivery-time rating
$T_r, \underline{t}_r$	Random variable and lower bound of delivery-time rating
$T_a, \bar{t}_a$	Random variable and upper bound of actual delivery time
$\varepsilon, \bar{\varepsilon}$	Random component and upper bound on random component of the actual delivery time
t_c	Delivery-time conformance
k	The unit impact of consumer satisfaction on delivery-time ratings
ϕ	The unit impact of q on v
λ	Elasticity of the marginal shipping cost reduction with respect to promised delivery time
α	The unit impact of delivery-time conformance on utility
β	The unit impact of promised delivery time on actual delivery time
γ	The unit impact of delivery time on utility
D, π_R, π_S	Aggregate demand, retailer’s profit, supplier’s profit
Decision variable	Description
t	Promised delivery time
w	Wholesale price
p	Retail price

4 Supply Chain Analysis

Next, we find the optimal prices and promised delivery time that maximize the profits of the supplier and the retailer. As mentioned before, the dominant fulfillment model in most e-commerce operations is drop-shipping. Under this model, the supplier is the leader who sets the wholesale price w and promised delivery time t , and the retailer is the follower who sets retail price p . Once a consumer buys the product, the retailer sends the order information to the supplier, who then processes the payment and issues a shipping order.

4.1 Main Scenario: Available Delivery-Time Ratings and Endogenous Pricing

We construct the supplier’s expected profit function as $\pi_S^{\mathcal{A}}(w, t) = [w - c - s(t)]D^{\mathcal{A}}$, where c denotes the supplier’s unit acquisition cost, $s(t)$ is the per unit delivery cost dependent on promised delivery time, and $D^{\mathcal{A}}$ is the expected demand in the presence of delivery-time ratings as given in (9). Because the supplier incurs a higher cost when promising shorter delivery times to consumers, $s(t)$ is decreasing in t , i.e., $s'(t) \leq 0$. Moreover, $s''(t) \geq 0$, because the marginal

cost decrease is usually larger for the short promised times than for long promised times. The retailer's expected profit function is $\pi_R^A(p) = (p - w)D^A$. As $\partial D^A / \partial p < 0$ according to (9), we find that $\partial \pi_S^A / \partial p < 0$.

Lemma 1 *Given a wholesale price w and a promised delivery time t , the optimal retail price is uniquely obtained as*

$$p^{A*}(w, t) = \frac{k(1 - \beta)(\bar{v} + w - \gamma t)t + 2\alpha(t_r - \underline{t}_r)}{2k(1 - \beta)t}$$

when delivery-time ratings are available and pricing is endogenous.

Next, we substitute $p^{A*}(w, t)$ into the supplier's profit function and have

$$\pi_S^A(w, t) = \frac{M[w - c - s(t)]}{\bar{q}\phi} \left[\frac{\bar{v} - w - \gamma t}{2} + \frac{\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right].$$

Proposition 1 *Letting t^{A*} be the solution to the following equation:*

$$kt^2(1 - \beta)[s'(t) + \gamma] + 2\alpha(t_r - \underline{t}_r) = 0, \quad (10)$$

we find that, if

$$2[s'(t^{A*}) + \gamma] + t^{A*}s''(t^{A*}) \geq 0, \quad (11)$$

then the optimal promised delivery time t^{A} is unique. The unique optimal wholesale price is*

$$w^{A*} = \frac{\bar{v} + c + s(t^{A*}) - \gamma t^{A*}}{2} + \frac{\alpha(t_r - \underline{t}_r)}{kt^{A*}(1 - \beta)}, \quad (12)$$

and the unique optimal retail price is

$$p^{A*} = \frac{3(\bar{v} - \gamma t^{A*}) + c + s(t^{A*})}{4} + \frac{3\alpha(t_r - \underline{t}_r)}{2kt^{A*}(1 - \beta)}. \quad (13)$$

Proposition 1 indicates that the inequality in (11) is a sufficient condition for the uniqueness of the optimal solutions. If condition (11) in Proposition 1 is not satisfied, i.e., $2[s'(t^{A*}) + \gamma] + t^{A*}s''(t^{A*}) < 0$, then $\partial^2 \pi_S^A(w^{A*}(t), t) / \partial (t)^2|_{t=t^{A*}} > 0$ and thus, t^{A*} , which uniquely satisfies equation (10), is not the optimal solution that maximizes the supplier's expected profit $\pi_S^A(w^{A*}(t), t)$. That is, $\pi_S^A(w^{A*}(t), t)$ is convex at t^{A*} , which implies that t^{A*} is the unique solution minimizing the supplier's profit $\pi_S^A(w^{A*}(t), t)$. Therefore, the supplier does not have any interior optimal solution but instead has a boundary optimal solution. To ensure that both marginal profit and demand are greater than 0, we should impose the condition $(\bar{v} - c - s(t) - \gamma t) / 2 + [\alpha(t_r - \underline{t}_r)] / [kt(1 - \beta)] > 0$ to find two realistic boundary points denoted by t_0 (which approaches 0) and t_1 (which makes the condition equal to 0). As the supplier's profit is 0 at t_1 , the optimal solution maximizing $\pi_S^A(w^{A*}(t), t)$ is not t_1 but the lower-bound point t_0 . This indicates that the delivery time promised by the supplier might be relatively short if condition (11) is not satisfied.

Since $s'(t) + \gamma = -[2\alpha(t_r - \underline{t}_r)] / [kt^2(1 - \beta)] < 0$ as indicated by (10), we can rewrite the inequality in (11) as $[ts''(t)] / [s'(t) + \gamma] \leq -2$. Moreover, we have

$$\frac{ts''(t)}{s'(t) + \gamma} < \frac{ts''(t)}{s'(t)} \leq -2.$$

Thus, the inequality in (11) is satisfied if the elasticity of the marginal shipping cost reduction with respect to promised delivery time, λ , satisfies the condition

$$\lambda \equiv \frac{\partial s'(t)/\partial t}{s'(t)/t} \leq -2. \quad (14)$$

The above inequality indicates that, *ceteris paribus*, a 1% increase in the supplier's promised delivery time can lead the marginal shipping cost reduction to decrease by more than 2%. The condition then implies that, if the time elasticity of the marginal shipping cost reduction is more than 2 (i.e., the marginal shipping cost reduction is elastic to the supplier's promised delivery time), then the optimal solutions are unique. How plausible is this elasticity value in practice? To address this question, we rely on previous research. García-Menéndez, Martínez-Zarzoso and De Miguel (2004) examined a total of 157 exporting firms in four Spanish exporting sectors and found that the shipping-cost elasticity of delivery time lies within the range $[-0.88, -0.13]$. Similarly, Rich, Holmblad and Hansen (2009) and Rich, Kveiborg and Hansen (2011) used relevant freight data from Denmark to show that the shipping-cost elasticity of delivery time varies lies within $[-0.53, -0.04]$. Consistently with these extant empirical results, the value of $1/\lambda$ is likely to be in the range $[-0.5, -0.04]$, or, $\lambda \in [-1/0.13, -1/0.5] = [-7.69, -2]$. Hence, we reasonably assume that $\lambda \leq -2$, so that the sufficient condition in Proposition 1 is satisfied and the optimal decisions are unique.

It follows that, when the supplier and the retailer implement the optimal decisions as defined in Proposition 1, the realized demand is

$$D^A = \frac{Md^A}{2\bar{q}\phi}, \text{ where } d^A \equiv \left[\frac{\bar{v} - \gamma t^{A*} - c - s(t^{A*})}{2} + \frac{\alpha(t_r - \underline{t}_r)}{kt^{A*}(1 - \beta)} \right], \quad (15)$$

and the two firms' profits are $\pi_S^A(w^{A*}, t^{A*}) = M(d^A)^2/(2\bar{q}\phi)$ and $\pi_R^A(p^{A*}) = M(d^A)^2/(4\bar{q}\phi)$.

Next, we conduct a sensitivity analysis of the optimal delivery and pricing decisions to investigate how the supply chain reacts to the changes in market conditions.

Corollary 1 *When delivery-time ratings are available and pricing is endogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time and with consumer sensitivity to delivery-time conformance.*

This corollary is consistent with the findings of Shang and Liu (2011) and Leng et al. (2024), who show that the optimal promised delivery time should decrease with consumer sensitivity to the promised delivery time. Nonetheless, Shang and Liu (2011) predict that the optimal delivery time increases when consumers care more about delivery-time conformance, whereas we, like Leng et al. (2024), find that the optimal delivery time decreases when consumers care more about delivery-time conformance. To understand this discrepancy, we relax our modeling assumptions one by one.

First, we consider a setting in which the retailer rather than the supplier fulfills the orders (for details, see Appendix B). We find that Corollary 1 holds in this scenario as well and therefore rule out our choice of the drop-shipping context as a potential explanation.

Second, we examine the possibility that consumers may use alternative sources of information to infer the actual delivery time. In particular, we investigate a setting in which two retailers compete, with one providing product-quality and delivery-time ratings and the other one not

publishing any ratings (for details, see Appendix C). Our analysis shows that Corollary 1 still holds in this two-retailer scenario as well. We can thus conclude that our results do not depend on our model of consumer inferences or the presence of competition.

Third, we consider a setting in which the retailer negotiates the wholesale price and delivery efforts with the supplier (for details, see Appendix D). There is anecdotal evidence of such bargaining. For example, the retailers Myer, David Jones, and JB Hi-Fi and also online cosmetics retailer Adore Beauty secure competitive wholesale prices through negotiations with their suppliers⁹. We analyze this scenario as a case of Nash bargaining and find that the result in Corollary 1 continues to hold. Hence, we rule out the potential explanation that our result is contingent upon our choice of competition model.

Finally, we note that the model of Shang and Liu (2011) regards pricing as exogenous whereas Leng et al. (2024) allow firms to jointly determine prices and the promised delivery time. We follow the latter and accordingly proceed to explore the role of pricing as a potential explanation for the differences between our results and those of Shang and Liu (2011).

4.2 Explanatory Analyses: Alternative Scenarios

If the ability to recoup shipping expenses via higher prices is what explains the difference between the results in Shang and Liu (2011) and the results in Corollary 1, then the difference should not arise if we consider exogenous pricing. We accordingly solve our model for t with fixed w and p .

4.2.1 The Scenario with Delivery-Time Ratings and with Exogenous Pricing

Given that the wholesale price w and the retail price p are fixed, the supplier's profit when delivery-time ratings are available is $\pi_S^{\mathcal{AF}}(w, t) = [w - c - s(t)]D^{\mathcal{A}}$. Using $D^{\mathcal{A}}$ in (9), we have

$$\pi_S^{\mathcal{AF}}(t) = \frac{M[w - c - s(t)]}{\bar{q}\phi} \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right],$$

where the superscript $\mathcal{AF}$ means that ratings are “available” and that prices are “fixed.”

Proposition 2 *When delivery-time ratings are available and pricing is exogenous, the supplier's optimal promised delivery time, $t^{\mathcal{AF}*}$, is the solution to the following equation:*

$$s'(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] + [w - c - s(t)] \left[\gamma + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^2} \right] = 0, \quad (16)$$

and is unique if

$$2 \left\{ s'(t^{\mathcal{AF}*}) \left[\bar{v} - 2\gamma t^{\mathcal{AF}*} - p \right] + \gamma[w - c - s(t^{\mathcal{AF}*})] \right\} + t^{\mathcal{AF}*} s''(t^{\mathcal{AF}*}) \left[\bar{v} - \gamma t^{\mathcal{AF}*} - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^{\mathcal{AF}*}} \right] \geq 0. \quad (17)$$

The scenario under which delivery-time ratings are available and pricing is exogenous possibly has a unique solution. Moreover, the realized demand is obtained as

$$D^{\mathcal{AF}} = \frac{M d^{\mathcal{AF}}}{\phi \bar{q}}, \text{ where } d^{\mathcal{AF}} \equiv \bar{v} - \gamma t^{\mathcal{AF}*} - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^{\mathcal{AF}*}},$$

and the supplier's profit is

$$\pi_S^{\mathcal{AF}}(t^{\mathcal{AF}*}) = \frac{M[-s'(t^{\mathcal{AF}*})]}{\phi \bar{q}} \frac{(1-\beta)k(t^{\mathcal{AF}*})^2}{(1-\beta)k(t^{\mathcal{AF}*})^2 \gamma + 2\alpha(t_r - t_r)} (d^{\mathcal{AF}})^2.$$

Corollary 2 *When delivery-time ratings are available and pricing is exogenous, the supplier's optimal demand and profit decrease with the retail price.*

The finding in Corollary 2 is consistent with results from the main scenario in which pricing is endogenous.

Corollary 3 *When delivery-time ratings are available and pricing is exogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

Corollary 3 is consistent with the findings of Shang and Liu (2011) regarding both consumer sensitivities. This indicates that the ability of the supply chain to increase prices is a *necessary* condition for the shortening of promised delivery times to be the optimal response to increases in consumer sensitivity to delivery conformance.

4.2.2 The Scenario without Delivery-Time Rating and with Endogenous Pricing

When delivery-time ratings are unavailable, consumers cannot use the ratings to predict their delivery utility. As discussed in Section 3, with no ratings information, consumers assume that the actual delivery time is $\bar{\varepsilon}^{\mathcal{N}} > \bar{\varepsilon}^{\mathcal{A}}$ and construe the expected conformance of delivery time as $t_c^{\mathcal{N}} = (1-\beta)t/\bar{\varepsilon}^{\mathcal{N}}$. The aggregate demand is $D^{\mathcal{N}}$ as given in (9). The supplier's and the retailer's expected profits are $\pi_S^{\mathcal{N}}(w, t) = [w - c - s(t)]D^{\mathcal{N}}$ and $\pi_R^{\mathcal{N}}(p) = (p - w)D^{\mathcal{N}}$, respectively.

When wholesale price w and retail price p are endogenous, the supplier's profits are given by

$$\pi_S^{\mathcal{N}}(t) = \frac{M[w - c - s(t)]}{\bar{q}\phi} \left[\bar{v} - \gamma t - p + \frac{\alpha(1-\beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right].$$

It is easy to derive from (9) that $\partial D^{\mathcal{N}}/\partial p < 0$ and $\partial \pi_S^{\mathcal{N}}/\partial p < 0$.

Proposition 3 *When delivery-time ratings are not available and pricing is endogenous, the supplier's optimal promised delivery time $t^{\mathcal{N}*}$ is uniquely determined as the solution to the following equation:*

$$\bar{\varepsilon}^{\mathcal{N}}[s'(t) + \gamma] = \alpha(1-\beta). \quad (18)$$

The supplier's optimal wholesale price is

$$w^{\mathcal{N}*} = \frac{[\bar{v} - \gamma t^{\mathcal{N}*} + c + s(t^{\mathcal{N}*})]\bar{\varepsilon}^{\mathcal{N}} + \alpha(1-\beta)t^{\mathcal{N}*}}{2\bar{\varepsilon}^{\mathcal{N}}}. \quad (19)$$

The retailer's optimal retail price is

$$p^{\mathcal{N}*} = \frac{[3(\bar{v} - \gamma t^{\mathcal{N}*}) + c + s(t^{\mathcal{N}*})]\bar{\varepsilon}^{\mathcal{N}} + 3\alpha(1-\beta)t^{\mathcal{N}*}}{4\bar{\varepsilon}^{\mathcal{N}}}. \quad (20)$$

Proposition 3 implies that, in contrast to the case with information disclosure, the case without

information disclosure always has a unique optimal solution. Thus, the demand is given by

$$D^{\mathcal{N}} = \frac{Md^{\mathcal{N}}}{4\phi\bar{q}}, \text{ where } d^{\mathcal{N}} \equiv \frac{\bar{\varepsilon}^{\mathcal{N}} [\bar{v} - c - s(t^{\mathcal{N}*}) - \gamma t^{\mathcal{N}*}] + \alpha(1 - \beta)t^{\mathcal{N}*}}{\bar{\varepsilon}^{\mathcal{N}}}, \quad (21)$$

and the profits of the supplier and the retailer are $\pi_S^{\mathcal{N}}(w^{\mathcal{N}*}, t^{\mathcal{N}*}) = M(d^{\mathcal{N}})^2/(8\bar{q}\phi)$ and $\pi_R^{\mathcal{N}}(p^{\mathcal{N}*}) = M(d^{\mathcal{N}})^2/(16\bar{q}\phi)$, respectively.

We again conduct a sensitivity analysis to identify a sufficient condition for the trade-off between delivery time and delivery-time conformance to arise.

Corollary 4 *When delivery-time ratings are not available and pricing is endogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

Corollary 4 suggests that endogenous pricing is not sufficient for the trade-off between delivery time and delivery-time conformance to arise.

4.2.3 The Scenario without Delivery-Time Rating and with Exogenous Pricing

Given that the wholesale price w and the retail price p are fixed, the supplier's profit is $\pi_S^{\mathcal{NF}}(w, t) = [w - c - s(t)]D^{\mathcal{N}}$. Using $D^{\mathcal{N}}$ from (9), we rewrite the supplier's profit as

$$\pi_S^{\mathcal{NF}}(w, t) = \frac{M[w - c - s(t)]}{\bar{q}\phi} \left[\bar{v} - \gamma t - p + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right],$$

where the superscript $\mathcal{NF}$ denotes “non available” delivery-time ratings and “fixed” prices.

Proposition 4 *When delivery-time ratings are not available and prices are exogenous, the supplier's optimal promised delivery time $t^{\mathcal{NF}*}$ is uniquely given by the solution to the following equation:*

$$-s'(t) \left[\bar{v} - \gamma t - p + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right] + [w - c - s(t)] \left[\frac{\alpha(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] = 0.$$

This scenario with no information disclosure has a unique solution, in which the demand is

$$D^{\mathcal{NF}} = \frac{Md^{\mathcal{NF}}}{\phi\bar{q}}, \text{ where } d^{\mathcal{NF}} \equiv \frac{\bar{\varepsilon}^{\mathcal{N}} [\bar{v} - \gamma t^{\mathcal{NF}*} - p] + \alpha(1 - \beta)t^{\mathcal{NF}*}}{\bar{\varepsilon}^{\mathcal{N}}},$$

and the profits are $\pi_S^{\mathcal{NF}} = M\bar{\varepsilon}^{\mathcal{N}} s'(t^{\mathcal{NF}*})(d^{\mathcal{NF}})^2 / [\phi\bar{q}(\alpha(1 - \beta) - \gamma\bar{\varepsilon}^{\mathcal{N}})]$ for the supplier.

Corollary 5 *When delivery-time ratings are not available and pricing is exogenous, the demand and supplier's profit decrease with the retail price.*

Corollary 6 *When delivery-time ratings are not available and pricing is exogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

Together, Corollaries 3, 4, and 6 imply that the trade-off between promised delivery time and delivery-time conformance can only be precluded by simultaneously making delivery-time ratings available and jointly determining prices and promised delivery times. This important result does not depend on the assumption of a drop-shipping fulfillment model; it also holds for

the retailer-fulfillment model (see Appendix B). In addition, our model does not assume that product-quality rating availability must increase consumer utility because it allows for the case $\bar{q} \geq q_r$. Hence, the result does not rest upon the premise that the availability of delivery-time ratings increases consumer utility (see Section 2). Furthermore, the value of $\bar{\varepsilon}^N$ does not play a role in the main scenario in Section 4.1 and thus, increasing the sensitivity to delivery-time conformance does not have a positive effect on the optimal promised delivery time. Conversely, this effect is negative in each of the other three scenarios regardless of how $\bar{\varepsilon}^A$ compares to $\bar{\varepsilon}^N$.

These results suggest that the availability of delivery-time rating allows the supply chain to generate value for consumers by reducing the uncertainty in the expected delivery time conformance. However, the supply chain may not have incentives to create such value unless it can capture some of it by adjusting prices.

4.3 The Profitability of Delivery-Time Rating Availability

We compare our results from the scenario with available ratings against those under the scenario with unavailable ratings to characterize the impact of delivery-time rating availability on the supply chain. We focus on the cases with endogenous pricing, as they are more consistent with the dataset and its institutional context.

Corollary 7 *The optimal promised delivery time when delivery-time ratings are available is shorter than that when the ratings are unavailable.*

Corollary 7 reveals that information disclosure leads the supplier to promise shorter delivery times. This happens mainly because, when delivery-time ratings are not available, consumers have no information on whether the supplier honors the promised delivery time and thus the expected conformance of delivery time does not increase with shorter promised delivery times. On the contrary, consumers may infer that suppliers are more likely to honor longer promised delivery times (i.e., $\partial t_c^N / \partial t > 0$). Therefore, shortening the promised delivery times does not necessarily increase demand and the supplier has no incentive to incur the additional costs associated with shorter delivery times. However, when delivery-time ratings are available, shorter promised delivery times can increase consumers' expected conformance of delivery time (i.e., $\partial t_c^A / \partial t < 0$) and increase demand. The gains from an increase in demand outweigh the costs of speedy delivery and the supply chain profits from reducing the promised delivery times.

To assess the effects of delivery-time rating availability on the wholesale and retail prices, we first define the supplier's unit shipping-cost change associated with the information disclosure as $\Delta s = s(t^{N*}) - s(t^{A*})$ and note that $\Delta s \leq 0$. Likewise, we define the delivery utility as $u(t_c) = \alpha t_c - \gamma t$ and the change in delivery utility that a consumer experiences because of information disclosure as Δu . We then note that, if $\Delta u \geq 0$, then information disclosure increases consumer delivery utility by Δu . Otherwise, if $\Delta u < 0$, then consumer delivery utility decreases by $|\Delta u|$.

Corollary 8 *Let $u(t_c^A) = \alpha t^{A*}(1 - \beta) / \bar{\varepsilon}^A - \gamma t^{A*}$ and $u(t_c^N) = \alpha t^{N*}(1 - \beta) / \bar{\varepsilon}^N - \gamma t^{N*}$. If and only if*

$$\Delta u \equiv u(t_c^A) - u(t_c^N) \geq \Delta s \equiv s(t^{N*}) - s(t^{A*}), \quad (22)$$

then the wholesale price when delivery-time ratings are available (i.e., w^{A}) is no smaller than the wholesale price when the ratings are not available (i.e., w^{N*}). If and only if $\Delta u < \Delta s$, w^{A*}*

is smaller than $w^{\mathcal{N}^*}$. Moreover, if and only if

$$\Delta u \geq \Delta s/3, \quad (23)$$

then the retail price when the delivery-time ratings are available (i.e., $p^{\mathcal{A}^*}$) is no smaller than the retail price when the same ratings are not available (i.e., $p^{\mathcal{N}^*}$). If and only if $\Delta u < \Delta s/3$, retail prices satisfy $p^{\mathcal{A}^*} < p^{\mathcal{N}^*}$.

Corollary 8 reveals that, even if the optimal promised delivery time under no information disclosure is greater than its counterpart under information disclosure, the optimal wholesale and retail prices may not be smaller when the delivery-time ratings are available to consumers. The corollary identifies three possible scenarios that are interpreted as follows.

Scenario 1: $\Delta u \geq \Delta s/3$. Condition (23) is satisfied (i.e., $\Delta u \geq \Delta s/3$ and $\Delta s \leq 0$) and therefore the condition in (22) is also satisfied (i.e., $\Delta u \geq \Delta s$ and $\Delta s \leq 0$). As a result, both the wholesale and retail prices under information disclosure are greater than those under no information disclosure, i.e., $w^{\mathcal{A}^*} \geq w^{\mathcal{N}^*}$ and $p^{\mathcal{A}^*} \geq p^{\mathcal{N}^*}$. The underlying intuition is that, if consumers benefit more than the supplier from the disclosure of delivery-time ratings, then, when disclosing the ratings information, the supplier and the retailer should raise their prices to offset the increase in shipping costs.

Scenario 2: $\Delta s \leq \Delta u < \Delta s/3 \leq 0$. Under this scenario, $w^{\mathcal{A}^*} \geq w^{\mathcal{N}^*}$ and $p^{\mathcal{A}^*} < p^{\mathcal{N}^*}$. Because $\Delta u < 0$, information disclosure reduces total consumer utility by a moderate extent. The supplier raises the wholesale price whereas the retailer decreases the retail price. As a result, the retailer's profit margin (i.e., $p^{\mathcal{A}^*} - w^{\mathcal{A}^*}$) is larger when information is disclosed.

Scenario 3: $\Delta u < \Delta s \leq 0$. Under this scenario, $w^{\mathcal{A}^*} < w^{\mathcal{N}^*}$ and $p^{\mathcal{A}^*} < p^{\mathcal{N}^*}$. The information disclosure significantly reduces total consumer utility below a certain threshold $\Delta s \leq 0$. Both the supplier and the retailer have to decrease their prices to compensate for consumers' losses.

Corollary 9 *The expected demand as well as the supplier's and the retailer's expected profits are higher when delivery-time ratings are available than when ratings are unavailable, if*

$$\Delta u + \Delta s \geq 0. \quad (24)$$

We learn from Corollary 9 that the valence of the effects of information disclosure on expected demand and the profitability of the supply chain depends on the condition in (24), where $\Delta u + \Delta s$ is regarded as the "system-wide value" resulting from the availability of delivery-time ratings. If the condition in (24) holds, then the conditions in (22) and (23) are satisfied as well. That is, a positive system-wide value leads to higher wholesale and retail prices. A non-negative system-wide value benefits the supply chain and provides the incentives for the retailer and the supplier to disclose the information of delivery-time ratings.

As per the discussion that follows Proposition 1, if condition (11) in Proposition 1 is not satisfied, the optimal solution maximizing the supplier's expected profit is a realistic lower-bound point. In such case, we find that Corollary 1 does not hold but Corollaries 7 and 8 may hold.

5 Empirical Support

We present empirical support for the theoretic results in Corollaries 7 and 9, which are the results that are tested with the Cainiao’s dataset. The dataset reports delivery-time ratings only when product-quality ratings are available and vice versa. Accordingly, we solve our game-theoretic models with endogenous prices once again but without both quality and delivery-time ratings. We find that the new results are qualitatively equivalent to the results for the case with product quality ratings but no delivery-time ratings. For details, see Appendix E where we obtain Corollaries F, G, and H by comparing the optimal promised delivery time, optimal prices, expected demand as well as profits when both quality ratings and delivery-time ratings are available and those when the two ratings are unavailable.

We then use the implications of these theoretic models to formulate hypotheses that match the features of the data generating process. First, we rely on Corollary H to posit the following.

Hypothesis 1 *Product sales are higher when ratings are available than when ratings are unavailable.*

A test of this hypothesis with secondary data faces the challenge of reverse causation. It is possible that the sales of new products are naturally not large enough to generate sufficient ratings and therefore delivery-time ratings may be absent as a consequence of low sales. To eliminate this reverse effect of sales on rating availability, we order the transactions of each seller according to their dates and identify the first transaction that was rated. We then discard all prior transactions. Hence, in the filtered sample, we exclude transactions in which published ratings were absent due to the lack of sales. We thus rule out the possibility of simultaneity bias.

Next, we construct reliable measures of unit sales and promised delivery times by aggregating the data so that the unit of observation is the combination of supplier, item, and rating availability level (available or unavailable). We only keep supplier and item combinations for which we observe both levels of rating availability. This filtering step, together with aggregation, reduce the sample to 7,798 observations. In this sample, we observe that the supplier sales are on average 1,018.98 units when ratings are not available ($n = 3,668$) and 9,610.93 when ratings are available ($n = 4,130$). We use the data to estimate regressions of the logarithm of sales on a dummy variable that equals one when delivery-time ratings are available and zero otherwise. We use supplier and subcategory fixed effects to control for unobserved heterogeneity and mitigate omitted-variable biases. The results, as given in Table 2, confirm that sales are higher when ratings are available (also see robustness tests in Table I in Online Appendix III). In particular, the sales are $\exp(2.282) = 9.796$ times higher ($p\text{-val} \leq 0.01$) when ratings are available. These results are consistent with Corollary H and therefore support Corollary 9.

We next rely on Corollary F to propose the following.

Hypothesis 2 *The optimal promised delivery time is shorter when ratings are available than when ratings are not available.*

We test this hypothesis with another regression model. Specifically, we use the average promised delivery time as dependent variable and find that it is 3.912 hours shorter ($p\text{-val} \leq 0.01$) when delivery-time ratings are available (see Table 2). This difference amounts to 7.4% of the average promised delivery time, equal to 52.95 hours (see Table B in Appendix A). Because these

results are consistent with Corollary F and support Corollary 7, they provide empirical support for the implications of our theoretical model.

Table 2: Empirical tests of implications of theoretical model.

	<i>Dependent Variables:</i>			
	log(Unit sales)		Avg. promised wait	
	(1)	(2)	(3)	(4)
Avg. promised wait	-0.043*** (0.001)	-0.039*** (0.001)		
Avg. price	-0.0004*** (0.0001)	-0.0003*** (0.0001)	-0.003*** (0.001)	-0.003*** (0.001)
Rating availability indicator		2.282*** (0.057)		-3.912*** (0.544)
Subcategory fixed effects	Yes	Yes	Yes	Yes
Supplier fixed effects	Yes	Yes	Yes	Yes
Observations	7,798	7,798	7,798	7,798
Adjusted R ²	0.707	0.759	0.981	0.981

Note: *p<0.1; **p<0.05; ***p<0.01.

6 Summary and Concluding Remarks

In this paper we consider a two-echelon supply chain consisting of a supplier and a retailer who serve an online market under the drop-shipping fulfillment model, which has been commonly adopted in online retailing. We rely on data from the Tmall supply chain to model and analyze consumer utility and to derive expected demand functions for both cases with and without delivery-time ratings. We allow the promised delivery time to affect consumer utility directly through its effect on expected waiting times and also indirectly through the effect of delivery-time ratings on expected delivery-time conformance. In agreement with the drop-shipping model, the supplier is in charge of product delivery and the retailer is only responsible for enabling transactions. Accordingly, the supplier determines the wholesale price and promised delivery time, whereas the retailer determines the retail price. We find that, under this scenario, the optimal promised delivery time is increasing in both consumer sensitivities to delivery time and to delivery-time conformance.

As extant publications have shown the optimal promised delivery time to be decreasing in consumer sensitivity to delivery time, in this paper we analyze additional models to explain the discrepancy. We find that the trade-off between delivery time and delivery-time conformance arises from the combination of delivery-time rating availability and the endogeneity of pricing (i.e., the ability of the supply chain to coordinate prices and promised delivery times). We show that this result also holds for the retailer-fulfillment model, in which the retailer rather than the supplier makes the promised delivery-time decision (see Appendix B), and also for a two-retailer case in which one retailer publishes product-quality and delivery-time ratings whereas the other one does not (see Appendix C). We further validate the result in a context of Nash bargaining where the retailer and the supplier bargain over the wholesale price and promised delivery-time (see Appendix D). Next, we find conditions for delivery-time rating availability to improve sales and profitability. Finally, we analyze the Tmall dataset to provide empirical support for two testable implications of our theoretic models.

The main implications of our analyses are summarized as follows.

1. Optimal promised delivery times are decreasing in consumer sensitivity to delivery time, no matter whether prices are endogenous or exogenous and no matter whether delivery-time ratings are available or not.
2. Optimal promised delivery times are increasing in consumer sensitivity to delivery-time conformance, unless pricing is endogenous and delivery-time ratings are available. If these two conditions hold, optimal promised delivery times are decreasing in consumer sensitivity to delivery conformance, and there is no trade-off between delivery times and delivery-time conformance.
3. Regardless of whether the supply chain uses the drop-shipping model or the retailer-fulfillment model, the optimal promised shipping time is shorter when rating information is disclosed than when it is not. For both fulfillment models, the impacts of information disclosure on the wholesale and retail prices are similar. If the information disclosure makes consumers' total utility increase greater than the supplier's unit shipping-cost increase, then the supplier and the retailer raise their prices when disclosing rating information. If consumers incur a medium total utility reduction after information disclosure, then the supplier raises the wholesale price whereas the retailer decreases the retail price. Otherwise, if consumers experience a sufficiently large total utility reduction, both the supplier and the retailer reduce their prices to compensate consumers for this loss.
4. For both the drop-shipping and the retailer fulfillment models, the supplier's and the retailer's incentives to disclose rating information depend on the system-wide value (i.e., the sum of consumers' total utility increase and the supply chain's unit shipping-cost reduction).
5. Because making delivery-time ratings available can shorten optimal delivery times, this strategy may not be profitable for online marketplaces that lack affordable access to a high delivery-speed infrastructure (e.g., marketplaces that operate in remote geographic areas or that lack capital to develop the capability in-house). Likewise, making delivery-time ratings available may not be profitable when short delivery times are cost-prohibitive or pricing restrictions are enforced (i.e., prices are exogenous or capped). These two possible scenarios could explain why some online retailers make delivery-time ratings available while others do not.

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Notes

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⁴For details, see <https://www.shoplazza.com/blog/shoplazzza-fulfillment-secrets-to-ship-your-products-by-cainiao-from-aliexpress>.

⁵See <https://dropshipping.com/article/aliexpress-premium-shipping/> and <https://cainiao.4px.com/site/productService>.

⁶See <https://www.scribd.com/document/595498034/Cainiao-Factsheet>.

⁷See, <https://www.ship24.com/shops/tmall-tracking>.

⁸See, <https://www.globaltimes.cn/page/202111/1238045.shtml>.

⁹See, <https://www.cifnews.com/article/1318> and <https://www.listcorp.com/asx/aby/adore-beauty-group/news/2024-annual-report-3091322.html>.

Appendix A Data

A.1 Sample selection

The initial dataset includes almost 160 million transactions at the item level (see Online Appendix I for a description of the raw data). After removing all observations with incomplete delivery information, we are left with 8,640,159 observations. Of these, about 60% are transactions in which seller and buyer are in the same city. After removing transactions involving multiple cities, we are left with 5,107,615 transactions. Among these transactions, 94.1% (or 4,804,499 transactions) are single item orders, among which 98.7% (or 4,741,544 transactions) have valid delivery times. This constitutes our final sample and preserves the distribution of relevant variables in the full sample. As shown now in Table A, the average price, promised wait, delivery delay, and delivery-time rating are very similar across all samples.

Table A: Effect of sample filtering on sample means of main empirical variables.

	Sample:			
	Initial	Same city	Single items	Valid
Promised wait (hours)	54.486	52.569	52.948	52.948
Delivery time (hours)	-18.135	-16.972	-17.161	-17.161
Price (CNY)	387.546	495.869	510.469	512.602
Delivery time rating	4.867	4.868	4.865	4.867
Rating availability indicator	0.939	0.935	0.932	0.932
Same city indicator	0.591	1.000	1.000	1.000
Single item indicator	0.933	0.941	1.000	1.000
Valid delivery time indicator	0.992	0.987	0.987	1.000
Sample size	8,640,159	5,107,615	4,804,499	4,741,544

A.2 Transformations

Delivery time. The data shows that deliveries take place 24hrs a day. Hence, we subtract the time stamp of the payment (indicating the order has been placed) from the time stamp of the buyer’s sign off (indicating the time of the delivery) to obtain the delivery time.

Promised wait. The original data reports the promised delivery speed coded as a numeric variable with values in the set $\{0,1,2,3, \text{NA}\}$. We recorded these values into a numeric promised wait relying on our exploration of the data and a thorough investigation of the shipping policy of Tmall at the time the data were collected. The data show that a promised speed coded as 1 corresponds to orders placed before 11:00am and to be delivered the end of the same day. The data also showed that, for orders with a promised speed coded as 2, orders are delivered before

the end of the next day. Orders with promised speed coded as 3 are most often delivered within a three-day window. Most orders with promised speed coded as 0 or a missing value are delivered within a week time. We compute the promised wait with these inferred delivery deadlines and the time the order was placed.

A.3 Descriptive statistics

Descriptive statistics of the main variables appear in Table B.

Table B: Descriptive statistics of final sample ($n = 4,741,544$).

Variable	Mean	Std. Dev.	Median	Min.	Max.	25 Pctl.	75 Pctl.
Promised wait (hours)	52.95	24.56	38.60	0.37	95.98	32.80	78.68
Delivery time (hours)	35.79	21.39	30.87	0.25	740.13	23.48	45.08
Price (CNY)	512.60	893.15	158.82	0.01	39,161.47	65.41	509.81
Quantity	1.04	0.59	1.00	1.00	288.00	1.00	1.00
Delivery time rating	4.82	0.08	4.82	0.50	5.00	4.78	4.86
Product quality rating	4.85	0.08	4.86	0.00	5.00	4.82	4.89
Service quality rating	4.81	0.08	4.81	0.50	5.00	4.78	4.86
Rating availability indicator	0.93	0.25	1.00	0.00	1.00	1.00	1.00

Appendix B Extension to the Retailer-Fulfillment Case

As noted before, while the drop-shipping model is dominant in the Cainiao's network, the retailer fulfillment model is common in practice as well. Here, we replicate our main analyses for the retailer fulfillment model to assess the generality/robustness of our main results. Under this fulfillment model, the retailer is responsible for delivery. When a consumer places an order, the retailer directly ships the product. The retailer promises a delivery time t and absorbs unit delivery cost $\tilde{s}(t)$ that satisfies $\tilde{s}'(t) \leq 0$ and $\tilde{s}''(t) \geq 0$ and that may or may not differ from the unit delivery cost absorbed by the supplier in the drop-shipping model [i.e., $s(t)$].

B.1 The Scenario with Delivery-Time Ratings and with Endogenous Pricing

We first consider the scenario in which the supply chain discloses delivery-time ratings to consumers and prices are endogenous. Hence, the supplier determines an optimal wholesale price to maximize his expected profit $\tilde{\pi}_S^A(w) = (w - c)D^A$ and the retailer determines the optimal retail price and the optimal promised delivery time to maximize her expected profit $\tilde{\pi}_R^A(p, t) = [p - w - \tilde{s}(t)]D^A$.

Proposition 5 *When the supply chain adopts the retailer fulfillment model and discloses delivery-time ratings to consumers, the optimal promised delivery time $\tilde{t}^{A*}$ is the solution to the equation*

$$kx^2(1 - \beta)[\tilde{s}'(t) + \gamma] + 2\alpha(t_r - \underline{t}_r) = 0. \quad (25)$$

If

$$2[\tilde{s}'(\tilde{t}^{A*}) + \gamma] + \tilde{t}^{A*}\tilde{s}''(\tilde{t}^{A*}) \geq 0, \quad (26)$$

then the optimal promised delivery time $\tilde{t}^{A*}$, wholesale price $\tilde{w}^{A*}$, and retail price $\tilde{p}^{A*}$ are unique. The optimal wholesale and retail prices are

$$\begin{cases} \tilde{w}^{A*} = \frac{\bar{v} + c - \tilde{s}(\tilde{t}^{A*}) - \gamma\tilde{t}^{A*}}{2} + \frac{\alpha(t_r - \underline{t}_r)}{k\tilde{t}^{A*}(1 - \beta)}, \\ \tilde{p}^{A*} = \frac{3(\bar{v} - \gamma\tilde{t}^{A*}) + c + \tilde{s}(\tilde{t}^{A*})}{4} + \frac{3\alpha(t_r - \underline{t}_r)}{2k\tilde{t}^{A*}(1 - \beta)}. \end{cases} \quad (27)$$

Proposition 5 reveals that the sufficient condition in (26) as well as the results for the optimal promised delivery time and retail price are similar in the retailer fulfillment and drop-shipping models, differing only in the unit delivery cost function [i.e., $s(t)$ and $\tilde{s}(t)$ are used in the drop-shipping and retailer fulfillment models, respectively]. As we argued in Section 4.1, the sufficient condition in (11) is very likely to occur in reality. Hence, the condition in (26) is likely to hold as well. Any difference in the optimal promised delivery time and retail price across the two business models is a function of the differences between $s(t)$ and $\tilde{s}(t)$. Next we replicate the sensitivity analysis.

Corollary A *In the retailer-fulfillment case, when delivery-time ratings are available and pricing is endogenous, the optimal promised delivery time decreases both with consumer sensitivity to delivery time and with consumer sensitivity to delivery conformance.*

B.2 The Scenario with Delivery-Time Ratings and with Exogenous Pricing

Given that wholesale price w and retail price p are fixed, the retailer's profits are given by

$$\tilde{\pi}_R^{\mathcal{AF}}(t) = \frac{M[p - w - \tilde{s}(t)]}{\bar{q}\phi} \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right].$$

Proposition 6 *In the retailer-fulfillment case, when delivery-time ratings are available and pricing is exogenous, the optimal promised delivery time, $\tilde{t}^{\mathcal{AF}*}$, is the solution to the following equation:*

$$\tilde{s}'(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] + [p - w - \tilde{s}(t)] \left[\gamma + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^2} \right] = 0, \quad (28)$$

and is unique if

$$\begin{aligned} & 2 \left\{ \tilde{s}'(\tilde{t}^{\mathcal{AF}*}) [\bar{v} - 2\gamma\tilde{t}^{\mathcal{AF}*} - p] + \gamma[p - w - \tilde{s}(\tilde{t}^{\mathcal{AF}*})] \right\} \\ & + \tilde{t}^{\mathcal{AF}*} \tilde{s}''(\tilde{t}^{\mathcal{AF}*}) \left[\bar{v} - \gamma\tilde{t}^{\mathcal{AF}*} - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)k\tilde{t}^{\mathcal{AF}*}} \right] \geq 0. \end{aligned} \quad (29)$$

An ensuing sensitivity analysis yields the following result.

Corollary B *When delivery-time ratings are available and pricing is exogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

B.3 The Scenario without Delivery-Time Rating and with Endogenous Pricing

We investigate a retailer-fulfillment supply chain that does not disclose delivery-time ratings to consumers. When the ratings information is unavailable, consumers cannot infer actual delivery

time $\bar{\varepsilon}$ and therefore assume that $\bar{\varepsilon} = \bar{\varepsilon}^{\mathcal{N}} > \bar{\varepsilon}^{\mathcal{A}}$. The two firms' expected profits are

$$\begin{cases} \tilde{\pi}_S^{\mathcal{N}}(w) = \frac{M[w - c]}{\bar{q}\phi} \left\{ \frac{\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - \gamma t - p) + \alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right\}, \\ \tilde{\pi}_R^{\mathcal{N}}(p, t) = \frac{M[p - w - \tilde{s}(t)]}{\bar{q}\phi} \left\{ \frac{\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - \gamma t - p) + \alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right\}. \end{cases}$$

Proposition 7 *For the retailer-fulfillment model, when the supply chain does not disclose the delivery-time ratings and prices are endogenous, the optimal promised delivery time $\tilde{t}^{\mathcal{N}*}$ is uniquely found by solving the following equation for t :*

$$\bar{\varepsilon}^{\mathcal{N}}[\tilde{s}'(t) + \gamma] = \alpha(1 - \beta). \quad (30)$$

The optimal wholesale and retail prices are obtained as

$$\begin{cases} \tilde{w}^{\mathcal{N}*} = \frac{\bar{\varepsilon}^{\mathcal{N}}[\bar{v} - \gamma\tilde{t}^{\mathcal{N}*} + c - \tilde{s}(\tilde{t}^{\mathcal{N}*})] + \alpha\tilde{t}^{\mathcal{N}*}(1 - \beta)}{2\bar{\varepsilon}^{\mathcal{N}}}, \\ \tilde{p}^{\mathcal{N}*} = \frac{\bar{\varepsilon}^{\mathcal{N}}[3\bar{v} - 3\gamma\tilde{t}^{\mathcal{N}*} + c + \tilde{s}(\tilde{t}^{\mathcal{N}*})] + 3\alpha\tilde{t}^{\mathcal{N}*}(1 - \beta)}{4\bar{\varepsilon}^{\mathcal{N}}}. \end{cases} \quad (31)$$

Corollary C *For the retailer-fulfillment case, when delivery-time ratings are not available and pricing is endogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

B.4 The Scenario without Delivery-Time Rating and with Exogenous Pricing

Given a fixed wholesale price w and a retail price p , we develop the retailer's profit as

$$\tilde{\pi}_R^{\mathcal{NF}}(p, t) = \frac{M[p - w - \tilde{s}(t)]}{\bar{q}\phi} \left[\bar{v} - \gamma t - p + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right].$$

Proposition 8 *For the retailer-fulfillment case, when the delivery-time ratings are not available and prices are exogenous, the optimal promised delivery time $\tilde{t}^{\mathcal{NF}*}$ is uniquely given by the solution to the following equation:*

$$-\tilde{s}'(t) \left[\bar{v} - \gamma t - p + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right] + [p - w - \tilde{s}(t)] \left[\frac{\alpha(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] = 0.$$

Corollary D *When the delivery-time ratings are not available and pricing is exogenous, the optimal promised delivery time decreases with consumer sensitivity to delivery time but increases with consumer sensitivity to delivery conformance.*

We can learn from Corollaries A, B, C, and D that, even if the retailer can set the promised delivery time, the trade-off between delivery-time and delivery-time-conformance exists when the delivery-time ratings are unavailable and pricing is exogenous. This result parallels the results drawn from the drop-shipping model, thus indicating that our main results obtained in Section 4.1 do not depend on whether the supplier or the retailer make the delivery time decision.

Appendix C Extension to Scenario with Two Different Retailers

Our models in Section 4 and Appendix B examine scenarios with a single supplier who interacts with a single retailer. In practice, a supplier may distribute offerings simultaneously through multiple retailers, each of which adheres to distinct delivery-time rating availability policies. This appendix accordingly considers a scenario under which a supplier sells through two retailers: one retailer has a subdivided review system including independent delivery-time ratings, while the other has an aggregated review system that does not include delivery-time ratings.

We let Retailer 1 be the retailer that offers the delivery-time ratings. As discussed in Section 2, a consumer's expected utility of buying one unit of an offering from Retailer 1 at price p_1 is $U_1 = \phi q + (1 - \phi) q_r - p_1 + \alpha t_c^A - \gamma t$. Retailer 2 does not publish separate delivery-time ratings, and therefore the expected utility of a consumer buying from Retailer 2 at price p_2 is $U_2 = q - p_2 + \alpha t_c^N - \gamma t$. The consumer chooses Retailer 2 over Retailer 1 if $U_2 \geq U_1$ and $U_2 \geq 0$. Conversely, the consumer chooses Retailer 1 if $U_1 \geq U_2$ and $U_1 \geq 0$. The consumer is indifferent between purchasing and not purchasing either product when $q = q_1 = [p_1 - (1 - \phi) q_r - \alpha t_c^A + \gamma t] / \phi$ or, equivalently, when $\phi > [p_1 - (1 - \phi) q_r - \alpha t_c^A + \gamma t] / (p_2 - \alpha t_c^N + \gamma t)$. The consumer is indifferent between purchasing from Retailer 1 or from Retailer 2 when $q = q_{12} = [p_2 - p_1 + \alpha (t_c^A - t_c^N) + (1 - \phi) q_r] / (1 - \phi)$. Therefore, the demand functions for Retailer 1 and Retailer 2 are

$$\begin{cases} D_1 = M \int_{q_1}^{q_{12}} g(q) dq = M \left[\frac{p_2 - p_1 + \alpha (t_c^A - t_c^N) + (1 - \phi) q_r}{(1 - \phi) \bar{q}} - \frac{p_1 - (1 - \phi) q_r - \alpha t_c^A + \gamma t}{\phi \bar{q}} \right], \\ D_2 = M \int_{q_{12}}^{\bar{q}} g(q) dq = M \left[1 - \frac{p_2 - p_1 + \alpha (t_c^A - t_c^N) + (1 - \phi) q_r}{(1 - \phi) \bar{q}} \right]. \end{cases} \quad (32)$$

Given the demand functions in (32), we can develop the expected profits of the supplier and the two retailers as $\pi_S^{\mathcal{AN}}(w, t) = [w - c - s(t)] (D_1 + D_2)$, $\pi_{R1}^{\mathcal{AN}}(p_1) = (p_1 - w) D_1$ and $\pi_{R2}^{\mathcal{AN}}(p_2) = (p_2 - w) D_2$, respectively. Here, c and $s(t)$ denote the supplier's unit acquisition cost and per unit delivery cost, respectively. The superscript $\mathcal{AN}$ denotes that one retailer's ratings are "available" and the other's ratings are "not available." We again regard the promised delivery time and prices as endogenous.

Proposition 9 *When the supplier's offerings are sold through a retailer that discloses ratings and a retailer that does not disclose ratings, the optimal promised delivery time $t^{\mathcal{AN}*}$ is the solution to the equation:*

$$(2 + \phi) [s'(t) + \gamma] = \{\alpha(1 - \beta)\phi\} / \{\bar{\varepsilon}^N\} - \{4\alpha(t_r - \underline{t}_r)\} / \{kt^2(1 - \beta)\}. \quad (33)$$

If

$$2[s'(t^{\mathcal{AN}*}) + \gamma] + t^{\mathcal{AN}*} s''(t^{\mathcal{AN}*}) \geq \{2(1 - \beta)\alpha\phi\} / \{(2 + \phi)\bar{\varepsilon}^N\}, \quad (34)$$

then the optimal promised delivery time $t^{\mathcal{AN}*}$, wholesale price $w^{\mathcal{AN}*}$, and retail prices $p_1^{\mathcal{AN}*}$,

$p_2^{\mathcal{AN}^*}$ are unique. The optimal wholesale and retail prices are

$$\begin{cases} w^{\mathcal{AN}^*} = \frac{2\bar{v} + \phi\bar{q} + (2 + \phi) [c + s(t^{\mathcal{AN}^*}) - \gamma x^{\mathcal{AN}^*}] + \alpha (2t_c^{\mathcal{A}^*} + \phi t_c^{\mathcal{N}^*})}{2(2 + \phi)}, \\ p_1^{\mathcal{AN}^*} = \frac{2(3 - \phi)\bar{v} - \phi\bar{q} + (2 + \phi) [c + s(t^{\mathcal{AN}^*})] + 3(\phi - 2)\gamma t^{\mathcal{AN}^*} + 2\alpha(3 - \phi)t_c^{\mathcal{A}^*} - \alpha\phi t_c^{\mathcal{N}^*}}{2(4 - \phi)}, \\ p_2^{\mathcal{AN}^*} = \frac{[8 + (3 - 2\phi)\phi](\bar{q} + \alpha t_c^{\mathcal{N}^*}) + 2(1 - \phi)(\bar{v} + \alpha t_c^{\mathcal{A}^*}) + 3(2 + \phi)[c + s(t^{\mathcal{AN}^*})] - F}{2(4 - \phi)(2 + \phi)}, \end{cases}$$

where $t_c^{\mathcal{A}^*} = 2(t_r - \underline{t}_r) / [k(1 - \beta)t^{\mathcal{AN}^*}]$, $t_c^{\mathcal{N}^*} = (1 - \beta)t^{\mathcal{AN}^*} / \bar{\varepsilon}^{\mathcal{N}}$ and $F = (2 + \phi)(5 - 2\phi)\gamma t^{\mathcal{AN}^*}$.

We learn from Proposition 9 that the sufficiency condition for the uniqueness of the optimal solution parallels the sufficiency condition in (11) in Proposition 1, thereby aligning with typical real-world scenarios. In addition, we find that if the condition in (34) is satisfied, it necessarily follows that the condition in (11) is also fulfilled.

Corollary E *When a supplier sells through both a retailer that offers the delivery-time ratings and a retailer that does not, the optimal promised delivery time decreases both with consumer sensitivity to delivery time and with consumer sensitivity to delivery conformance.*

The findings in Corollary E are consistent with those in Corollary 1 (which is obtained from our main scenario). When incorporating an additional channel without delivery-time ratings alongside the existing channel with available ratings, we can mitigate the trade-off between promised delivery time and delivery-time conformance by coordinating the prices and promised delivery times. Therefore, our extension indicates that the main results derived under the single retailer channel are robust as they continue to hold under the scenario with two different retailers.

Appendix D Extension to Scenario with Nash Bargaining

In practice, it is possible that some retailers have bargaining power over suppliers, which allows them to negotiate the wholesale prices and promised delivery time. In this appendix, we extend the main scenario with delivery-time ratings and with endogenous pricing to allow (i) the retailer and the supplier to first bargain over wholesale price $w^{\mathcal{NB}}$ and promised delivery time $t^{\mathcal{NB}}$ and then (ii) the retailer to set retail price $p^{\mathcal{NB}}$. Here, the superscript $\mathcal{NB}$ denotes that we model the bargaining game as a standard Nash bargaining problem (Li and Zhang 2023, Avinadav, Chernonog and Khmelnitsky 2025). Then, if the bargaining process is successful, the profits of the supplier and the retailer are $\pi_S^{\mathcal{NB}} = [w - c - s(t)]D^{\mathcal{A}}$ and $\pi_R^{\mathcal{NB}} = (p - w)D^{\mathcal{A}}$, respectively. To solve the game, we first derive the optimal retail price $p^{\mathcal{NB}}(w, t) = (\bar{v} + w - \gamma t) / 2 + [\alpha(t_r - \underline{t}_r)] / [k(1 - \beta)t]$. Next, substituting $p^{\mathcal{NB}}(w, t)$ into the supplier's and retailer's profit functions, we obtain

$$\begin{cases} \pi_S^{\mathcal{NB}}(w, t) = \frac{M[w - c - s(t)]}{\bar{q}\phi} \left[\frac{\bar{v} - w - \gamma t}{2} + \frac{\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right], \\ \pi_R^{\mathcal{NB}}(w, t) = \frac{M}{\bar{q}\phi} \left[\frac{\bar{v} - w - \gamma t}{2} + \frac{\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right]^2. \end{cases}$$

Let parameter $\psi \in [0, 1]$ be the bargaining power of the supplier and the retailer's bargaining power be $1 - \psi$. The Nash bargaining solution is the pair of $w^{\mathcal{NB}^*}$ and $t^{\mathcal{NB}^*}$ that solves $\max_{w, t} [\pi_S^{\mathcal{NB}}(w, t)]^\psi [\pi_R^{\mathcal{NB}}(w, t)]^{1 - \psi}$.

Proposition 10 *When the supplier bargains the wholesale price and promised delivery time with the retailer, the optimal promised delivery time $t^{\mathcal{NB}^*}$ is the solution to the equation:*

$$kt^2(1 - \beta)[s'(t) + \gamma] + 2\alpha(t_r - \underline{t}_r) = 0. \quad (35)$$

If

$$2[s'(t^{\mathcal{NB}^*}) + \gamma] + t^{\mathcal{NB}^*} s''(t^{\mathcal{NB}^*}) \geq 0, \quad (36)$$

then the optimal promised delivery time $t^{\mathcal{NB}^*}$, wholesale price $w^{\mathcal{NB}^*}$ and retail price $p^{\mathcal{NB}^*}$ are unique. The optimal wholesale and retail prices are

$$\begin{cases} w^{\mathcal{NB}^*} = \psi \left[\frac{\bar{v} + c + s(t^{\mathcal{NB}^*}) - \gamma t^{\mathcal{NB}^*}}{2} + \frac{\alpha(t_r - \underline{t}_r)}{k(1 - \beta)t^{\mathcal{NB}^*}} \right] + (1 - \psi)[c + s(t^{\mathcal{NB}^*})], \\ p^{\mathcal{NB}^*} = \frac{(2 + \psi)(\bar{v} - \gamma t^{\mathcal{NB}^*}) + \psi[c + s(t^{\mathcal{NB}^*})]}{4} + \frac{(2 + \psi)\alpha(t_r - \underline{t}_r)}{2k(1 - \beta)t^{\mathcal{NB}^*}} + \frac{(1 - \psi)[c + s(t^{\mathcal{NB}^*})]}{2}. \end{cases} \quad (37)$$

Proposition 10 draws a conclusion that aligns with the findings presented in Section 4.1. Both the equation and the sufficiency condition for the uniqueness of the optimal promised delivery time are consistent with those in Proposition 1. This implies that our main findings regarding the optimal promised delivery time $t^{\mathcal{NB}^*}$ hold regardless of whether the retailer and the supplier negotiate the wholesale price and promised delivery time or not. Indeed, our analysis for the main scenario in Section 4.1 is a special case of the Nash Bargaining game in which the supplier has a full bargaining power (i.e., $\psi = 1$). That is, when $\psi = 1$, the optimal solution (37) degenerates into the optimal solution of the main scenario in Section 4.1. Since the equation in (35) is identical to that in (10), we can conclude that the optimal promised delivery time $t^{\mathcal{NB}^*}$ decreases with consumer sensitivity to delivery time and with consumer sensitivity to delivery-time conformance. Hence, the results in Corollary 1 also hold when the bargaining takes place in the supply chain.

Appendix E Theoretic Analysis for Empirical Tests

E.1 Analysis without Product-Quality Rating and Delivery-Time Rating

We consider the drop-shipping fulfillment model with endogenous pricing when both t_r and q_r are unavailable. As discussed in Section 3, when the ratings information is unavailable, consumers assume that the actual delivery time is $\bar{\varepsilon}^{\mathcal{N}} > \bar{\varepsilon}^{\mathcal{A}}$ in (4) and predict the quality of delivery to be $t_c^{\mathcal{N}} = (1 - \beta)t/\bar{\varepsilon}^{\mathcal{N}}$. Then, we have $U \geq 0$ if $q \geq \underline{q}^{\mathcal{N}} \equiv [\bar{\varepsilon}^{\mathcal{N}}p - \alpha(1 - \beta)t]/\bar{\varepsilon}^{\mathcal{N}} + \gamma t$, and the demand function is

$$D = D^{\mathcal{N}} \equiv M \int_{\underline{q}^{\mathcal{N}}}^{\bar{q}} g(q) dq = M [\bar{q} - \underline{q}^{\mathcal{N}}] / [\bar{q}]. \quad (38)$$

The supplier's and the retailer's expected profits are $\pi_S^{\mathcal{N}}(w, t) = [w - c - s(t)]D^{\mathcal{N}}$ and $\pi_R^{\mathcal{N}}(p) = (p - w)D^{\mathcal{N}}$, respectively.

Proposition 11 *For the drop-shipping model, when pricing is endogenous and the supply chain does not release quality or delivery-time ratings to consumers, the optimal promised delivery time $t^{\mathcal{N}^*}$ is uniquely determined by solving the following equation for t :*

$$\bar{\varepsilon}^{\mathcal{N}}[s'(t) + \gamma] = \alpha(1 - \beta). \quad (39)$$

The supplier's optimal wholesale price is

$$w^{\mathcal{N}*} = \{\bar{\varepsilon}^{\mathcal{N}}[\bar{q} - \gamma t^{\mathcal{N}*} + c + s(t^{\mathcal{N}*})] + \alpha t^{\mathcal{N}*}(1 - \beta)\} / \{2\bar{\varepsilon}^{\mathcal{N}}\}. \quad (40)$$

The retailer's optimal retail price is

$$p^{\mathcal{N}*} = \{\bar{\varepsilon}^{\mathcal{N}}[3(\bar{q} - \gamma t^{\mathcal{N}*}) + c + s(t^{\mathcal{N}*})] + 3\alpha t^{\mathcal{N}*}(1 - \beta)\} / \{4\bar{\varepsilon}^{\mathcal{N}}\}. \quad (41)$$

It follows that demand is given by

$$D^{\mathcal{N}} = \{M d^{\mathcal{N}}\} / \{4\bar{q}\}, \text{ where } d^{\mathcal{N}} \equiv \{\bar{\varepsilon}^{\mathcal{N}}[\bar{q} - c - s(t^{\mathcal{N}*}) - \gamma t^{\mathcal{N}*}] + \alpha t^{\mathcal{N}*}(1 - \beta)\} / \{\bar{\varepsilon}^{\mathcal{N}}\}, \quad (42)$$

and the supplier's and the retailer's profits are $\pi_S^{\mathcal{N}}(w^{\mathcal{N}*}, t^{\mathcal{N}*}) = M(d^{\mathcal{N}})^2/(8\bar{q})$ and $\pi_R^{\mathcal{N}}(p^{\mathcal{N}*}) = M(d^{\mathcal{N}})^2/(16\bar{q})$, respectively.

E.2 Comparison against the Main Scenario

We first compare the optimal promised delivery times when product-quality and delivery-time ratings are both available with those when both ratings are unavailable

Corollary F *The optimal promised delivery times are shorter when product-quality and delivery-time ratings are both available than when neither of them is available.*

We note $\Delta s = s(t^{\mathcal{N}*}) - s(t^{\mathcal{A}*}) \leq 0$ and redefine Δu accordingly. Then, we compare the wholesale and retail prices when both ratings are available with those when no rating is available.

Corollary G *Let $u(t_c^{\mathcal{A}}) = \alpha t^{\mathcal{A}*}(1 - \beta)/\bar{\varepsilon}^{\mathcal{A}} - \gamma t^{\mathcal{A}*}$ and $u(t_c^{\mathcal{N}}) = \alpha t^{\mathcal{N}*}(1 - \beta)/\bar{\varepsilon}^{\mathcal{N}} - \gamma t^{\mathcal{N}*}$. The wholesale price when product-quality and delivery-time ratings are available (i.e., $w^{\mathcal{A}*}$) is no smaller than the wholesale price when such ratings are not available (i.e., $w^{\mathcal{N}*}$), if and only if*

$$\Delta u \equiv [\bar{v} + u(t_c^{\mathcal{A}})] - [\bar{q} + u(t_c^{\mathcal{N}})] \geq \Delta s \equiv s(t^{\mathcal{N}*}) - s(t^{\mathcal{A}*}). \quad (43)$$

The retail price when product-quality and delivery-time ratings are available (i.e., $p^{\mathcal{A}}$) is no smaller than the retail price when such ratings are not available (i.e., $p^{\mathcal{N}*}$), if and only if*

$$\Delta u \geq \Delta s/3. \quad (44)$$

We also compare the expected demand and two firms' expected profits when both ratings are available with those when such ratings are not available.

Corollary H *The expected demand as well as the supplier's and the retailer's expected profits are both higher when product-quality and delivery-time ratings are available than when such ratings are not available, if*

$$\Delta u + \Delta s \geq 0. \quad (45)$$

E-Companion

“Retailer-Supplier Coordination of Pricing and Delivery Ratings Availability Decisions in Online Marketplaces”

Online Appendix I Context and dataset description

The information available to consumers on the product pages of T-mall’s platform is illustrated by the screenshots in Figure I. There, one can observe three separate ratings for product, customer service, and delivery time.

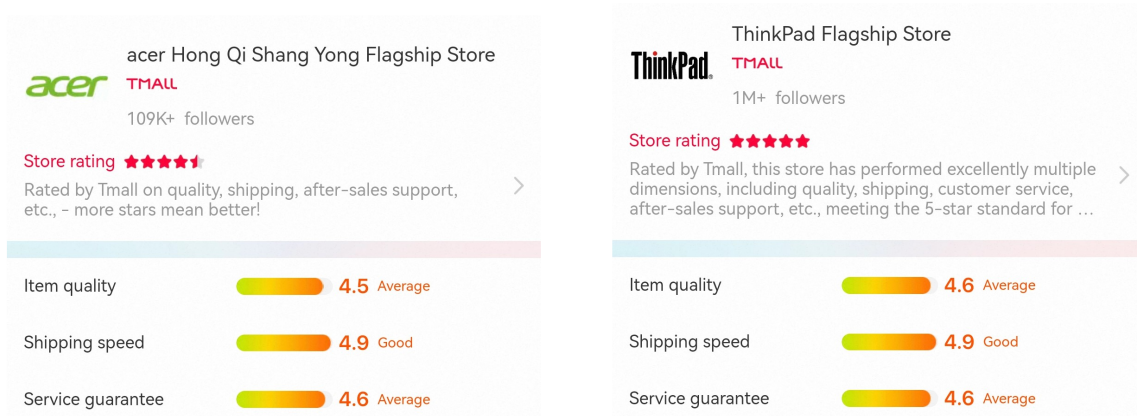


Figure I: Examples of seller ratings on Tmall’s platform.

The *original* data set provided by Cainiao reports orders served from 2017/01/01 to 2017/07/31. The data are provided in *five* tables.

The *first* table provides detailed information about customer orders. The available fields as follows: date of payment (e.g., 20170101), ID of the order (e.g., 123456), order description (which includes item id, quantity, and payment amount for all items in the order, e.g. 123:2:4.5; 234:2:35.5), time of payment rounded to 1 minute intervals (e.g., 2017-01-01 08:50:00), ID of the user who placed the order (e.g., 111), promised delivery speed (1: same day delivery, 2: next day delivery, 0 or null :no promise), whether the order is delivered from Cainiao’s warehouse, ID of the merchant (e.g., 222), and the user’s review score on the logistic service (scale from 1 to 5).

The *second* table contains meta-data for each item, including merchant, brand, and category information. The data fields are as follows: Date of item view (e.g., 20170101), ID of the item (e.g., 123), ID of the item at the e-commerce website (e.g., 456), ID of the merchant (e.g., 12), ID of the brand of the item (e.g., 11), ID of the main category of the item (e.g., 1), ID of the subcategory of the item (e.g., 2), total page view on PC (e.g., 100), total unique visitor count on app (e.g., 70), total unique visitor count on PC (e.g., 50), total page view on app (e.g., 150), and whether the item is delivered by Cainiao’s warehousing and fulfillment service (1: use Cainiao’s warehouse, 0: not use Cainiao’s warehouse).

The *third* table provides online traffic and review information for each merchant, aggregated at the subcategory level. The data fields are as follows: date of the snapshot (e.g., 20170101), ID of the merchant (e.g., 5), ID of the subcategory (e.g., 1), total page view on pc (e.g., 100), total unique visitor count on PC (e.g., 20), total page view on app (e.g., 150), total unique visitor count on app (e.g., 30), average review score on logistic service (range in 1-5), average review score on

order quality (range in 1-5), average review score on the quality of online purchase service (range in 1-5), and whether the merchant uses Cainiao's warehousing and fulfillment service (1: use Cainiao's warehouse, 0: not use Cainiao's warehouse).

The *fourth* table provides detailed information on the fulfillment logistics, including the dispatch of the package, the arrival and departure of the package at each facility of the logistics network, and the acceptance of the package by the customer. The data fields are as follows: ID of the purchase order (e.g., 12345), Date of the payment of the order (e.g., 20170101), ID of the logistic order (e.g., 123451), action being documented (CONSIGN: dispatch of the package from warehouse/merchant; GOT: package received by the carrier; ARRIVAL: arrive at the facility; DEPARTURE: leave the facility; SENT_SCAN: package left the delivery station; SIGNED: the buyer received the package; TRADE_SUCCESS: confirm the order is delivered; FAILURE: fail to deliver the order), the facility that handles the package at this particular event (e.g., 12), type of the facility (1: delivery station; 2: logistic transfer center; Null: no facility or facility type not categorized), ID of the city (e.g., 1), ID of the company that delivers the package (0 or 1), and the time that the event happened (e.g., 2017-01-01 08:50:00).

The *fifth* table reports inventory history, available only for merchants using Cainiao's warehousing and fulfillment service. Inventory is not relevant to our problem and hence we do not describe this table.

According to Cainiao "[a]ll data are anonymized and sampled in a way to not reflect any overall statistics or trend. The structure of the data is representative of the overall business operation, and we believe insights based on mining on this data would be beneficial to the industry as a whole. The data are confidential and authorized users are required to protect it from unauthorized or inadvertent disclosure." Hence, we only provide a summary description of the data that are relevant to our project.

Online Appendix II Proofs

Proof of Lemma 1. Using (9), we differentiate $\pi_R^A(p)$ once and twice w.r.t. p as

$$\frac{\partial \pi_R^A(p)}{\partial p} = \frac{2M\{-(1-\beta)kt[\gamma t/2 + p - w/2 - \phi\bar{q}/2 - (1-\phi)q_r/2] + \alpha(t_r - \underline{t}_r)\}}{kt\bar{q}\phi(1-\beta)},$$

and $\partial^2 \pi_R^A(p)/\partial p^2 = -2M/(\phi\bar{q}) < 0$. Equating $\partial \pi_R^A(p)/\partial p$ to zero and solving it for p , we obtain $p^{A*}(w, t)$ as given in this lemma. ■

Proof of Proposition 1. Taking the first- and second-order derivatives of $\pi_S^A(w, t)$ w.r.t. w , we have

$$\frac{\partial \pi_S^A(w, t)}{\partial w} = \frac{M\{kt(1-\beta)[\bar{v} + c + s(t) - \gamma t - 2w] + 2\alpha(t_r - \underline{t}_r)\}}{2\bar{q}kt\phi(1-\beta)},$$

where $\bar{v} = \bar{q}\phi + (1-\phi)q_r$, and $\partial^2 \pi_S^A(w, t)/\partial w^2 = -M/(\bar{q}\phi) < 0$. Solving the first order condition $\partial \pi_S^A(w, t)/\partial w = 0$ gives

$$w^{A*}(t) = \frac{\bar{v} + c + s(t) - \gamma t}{2} + \frac{\alpha(t_r - \underline{t}_r)}{kt(1-\beta)}.$$

Then, replacing w with $w^{A^*}(t)$, we rewrite the supplier's profit function as

$$\pi_S^A(w^{A^*}(t), t) = \frac{M[(1 - \beta)kt(c + s(t) + \gamma t - \bar{v}) - 2\alpha(t_r - \underline{t}_r)]^2}{8\bar{q}\phi[kt(1 - \beta)]^2}.$$

Differentiating $\pi_S^A(w^{A^*}(t), t)$ once w.r.t. t yields

$$\frac{\partial \pi_S^A(w^{A^*}(t), t)}{\partial t} = \eta[k(t)^2(1 - \beta)(s'(t) + \gamma) + 2\alpha(t_r - \underline{t}_r)],$$

where

$$\eta \equiv \frac{M[(1 - \beta)kt(c + s(t) + \gamma t - \bar{v}) - 2\alpha(t_r - \underline{t}_r)]}{4\bar{q}\phi[k(1 - \beta)]^2(t)^3}.$$

Obviously, $\eta \neq 0$, because, otherwise, the supplier's profit is zero. Therefore, the first order condition becomes

$$kt^2(1 - \beta)[s'(t) + \gamma] + 2\alpha(t_r - \underline{t}_r) = 0. \quad (i)$$

The second-order derivative of $\pi_S^A(w^{A^*}(t), t)$ is

$$\frac{\partial^2 \pi_S^A(w^{A^*}(t), t)}{\partial (t)^2} = \frac{\partial \eta}{\partial t}[k(t)^2(1 - \beta)(s'(t) + \gamma) + 2\alpha(t_r - \underline{t}_r)] + \eta kt(1 - \beta)[2(s'(t) + \gamma) + ts''(t)].$$

When the value of t satisfies the first order condition and the condition in (11) is satisfied, $\partial^2 \pi_S^A(w^{A^*}(t), t) / \partial (t)^2 \leq 0$. We thus prove the proposition. ■

Proof of Corollary 1. We differentiate (i) w.r.t. γ and α to obtain

$$\begin{aligned} \partial t^{A^*} / \partial \gamma &= -t^{A^*} / \{s''(t^{A^*})t^{A^*} + 2(s'(t^{A^*}) + \gamma)\} \leq 0, \\ \partial t^{A^*} / \partial \alpha &= -2(t_r - \underline{t}_r) / \{k(1 - \beta)t^{A^*}[s''(t^{A^*})t^{A^*} + 2(s'(t^{A^*}) + \gamma)]\} \leq 0, \end{aligned}$$

where the inequalities follow from (11), $\beta < 1$, and $t_r - \underline{t}_r \geq 0$. ■

Proof of Proposition 2. The retailer does make any decision and the supplier only decides on the promised delivery time. Taking the first- and second-order derivatives of $\pi_S^{AF}(t)$ w.r.t. t , we have

$$\begin{aligned} \frac{\partial \pi_S^{AF}(t)}{\partial t} &= -s'(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] \frac{M}{\phi \bar{q}} + [w - c - s(t)] \left[-\gamma - \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^2} \right] \frac{M}{\phi \bar{q}}, \\ \frac{\partial^2 \pi_S^{AF}(t)}{\partial t^2} &= 2 \left[s'(t) \left(\gamma + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^2} \right) + (w - c - s(t)) \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^3} \right] \frac{M}{\phi \bar{q}} \\ &\quad - s''(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] \frac{M}{\phi \bar{q}}. \end{aligned} \quad (ii)$$

We thus obtain the first and second order conditions as in (16) and (17), respectively. ■

Proof of Corollary 2. We differentiate D^{AF} once w.r.t. p and find

$$\frac{\partial D^{AF}}{\partial p} = \frac{M}{\phi \bar{q}} \left[-\gamma \frac{\partial t^{AF*}}{\partial p} - 1 - \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)k(t^{AF*})^2} \frac{\partial t^{AF*}}{\partial p} \right] < 0,$$

where $\partial t^{AF*} / \partial p < 0$ according to (16) and (17). Differentiating $\pi_S^{AF}(t^{AF*})$ once w.r.t. p gives

$\partial \pi_S^{\mathcal{AF}}(t^{\mathcal{AF}*}) / \partial p < 0$ according to (16) and $s'(t^{\mathcal{AF}*}) < 0$. ■

Proof of Corollary 3. We differentiate the first order condition in (ii) once w.r.t. γ and α to obtain

$$\begin{aligned} \frac{\partial t^{\mathcal{AF}*}}{\partial \gamma} &= [s'(t^{\mathcal{AF}*})t^{\mathcal{AF}*} - w + c + s(t^{\mathcal{AF}*})] / h(t^{\mathcal{AF}*}) \leq 0, \\ \frac{\partial t^{\mathcal{AF}*}}{\partial \alpha} &= -\frac{2[s'(t^{\mathcal{AF}*})t^{\mathcal{AF}*} + w - c - s(t^{\mathcal{AF}*})](t_r - \underline{t}_r)}{k(1-\beta)(t^{\mathcal{AF}*})^2 h(t^{\mathcal{AF}*})} > 0, \end{aligned}$$

where

$$\begin{aligned} h(t^{\mathcal{AF}*}) &= s''(t^{\mathcal{AF}*}) \left[\bar{v} - \gamma t^{\mathcal{AF}*} - p + \frac{2\alpha(t_r - \underline{t}_r)}{k(1-\beta)t^{\mathcal{AF}*}} \right] - 2s'(t^{\mathcal{AF}*}) \left[\gamma + \frac{2\alpha(t_r - \underline{t}_r)}{k(1-\beta)(t^{\mathcal{AF}*})^2} \right] \\ &\quad - [w - c - s(t^{\mathcal{AF}*})] \frac{4\alpha(t_r - \underline{t}_r)}{k(1-\beta)(t^{\mathcal{AF}*})^3}, \end{aligned}$$

and the inequalities follow from the first and second order conditions. ■

Proof of Proposition 3. We start with the retailer's optimal decision given the supplier's wholesale price w and promised delivery time t . Differentiating $\pi_R^{\mathcal{N}}(p)$ once and twice w.r.t. p gives $\partial \pi_R^{\mathcal{N}}(p) / \partial p = M[\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - 2p - \gamma t + w) + \alpha t(1 - \beta)] / (\phi \bar{q} \bar{\varepsilon}^{\mathcal{N}})$ and $\partial^2 \pi_R^{\mathcal{N}}(p) / \partial p^2 = -2M / \phi \bar{q} < 0$. Solving the first order condition $\partial \pi_R^{\mathcal{N}}(p) / \partial p = 0$, we can obtain the optimal (w, t) -dependent retail price as $p^{N*}(w, t) = [(\bar{v} + w - \gamma t)\bar{\varepsilon}^{\mathcal{N}} + \alpha t(1 - \beta)] / (2\bar{\varepsilon}^{\mathcal{N}})$.

Next, we substitute $p^{N*}(w, t)$ into the supplier's expected profit function $\pi_S^{\mathcal{N}}(w, t)$, and maximize the resulting profit to find the supplier's optimal decisions. Taking the first- and second-order derivatives of $\pi_S^{\mathcal{N}}(w, t)$ w.r.t. w , we have $\partial \pi_S^{\mathcal{N}}(w, t) / \partial w = M[\bar{\varepsilon}^{\mathcal{N}}(\bar{v} + c - 2w - \gamma t) + \bar{\varepsilon}^{\mathcal{N}}s(t) + \alpha t(1 - \beta)] / (2\phi \bar{q} \bar{\varepsilon}^{\mathcal{N}})$ and $\partial^2 \pi_S^{\mathcal{N}}(w, t) / \partial w^2 = -M / \bar{q} \phi < 0$. The optimal t -dependent wholesale price is $w^{N*}(t) = [\bar{\varepsilon}^{\mathcal{N}}(\bar{v} + c + s(t) - \gamma t) + \alpha t(1 - \beta)] / (2\bar{\varepsilon}^{\mathcal{N}})$. Replacing w with $w^{N*}(t)$ in $\pi_S^{\mathcal{N}}(w, t)$, we obtain $\pi_S^{\mathcal{N}}(w^{N*}(t), t) = M[\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - c - s(t) - \gamma t) + \alpha t(1 - \beta)]^2 / (8\phi(\bar{\varepsilon}^{\mathcal{N}})^2 \bar{q})$. Then, differentiating $\pi_S^{\mathcal{N}}(w^{N*}(t), t)$ once w.r.t. t yields

$$\frac{\partial \pi_S^{\mathcal{N}}(w^{N*}(t), t)}{\partial t} = \hat{\eta}[-\bar{\varepsilon}^{\mathcal{N}}s'(t) - \gamma \bar{\varepsilon}^{\mathcal{N}} + \alpha(1 - \beta)],$$

where

$$\hat{\eta} \equiv \frac{M[\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - c - s(t) - \gamma t) + \alpha t(1 - \beta)]}{4\phi(\bar{\varepsilon}^{\mathcal{N}})^2 \bar{q}}.$$

Note that $\hat{\eta} \neq 0$, because, otherwise, $\pi_S^{\mathcal{N}}(w, t) = 0$. We compute

$$\frac{\partial^2 \pi_S^{\mathcal{N}}(w^{N*}(t), t)}{\partial t^2} = \frac{\partial \hat{\eta}}{\partial t}[-\bar{\varepsilon}^{\mathcal{N}}s'(t) - \gamma \bar{\varepsilon}^{\mathcal{N}} + \alpha(1 - \beta)] - \hat{\eta}\bar{\varepsilon}^{\mathcal{N}}s''(t),$$

which is equal to $-\hat{\eta}\bar{\varepsilon}^{\mathcal{N}}s''(t)$ when the first order condition is satisfied. Letting t^{N*} satisfy the first order condition $\bar{\varepsilon}^{\mathcal{N}}s'(t) + \gamma \bar{\varepsilon}^{\mathcal{N}} - \alpha(1 - \beta) = 0$, $D^{\mathcal{N}} = M[\bar{\varepsilon}^{\mathcal{N}}(\bar{v} - p^{N*} - \gamma t^{N*}) + \alpha t^{N*}(1 - \beta)] / (\phi \bar{\varepsilon}^{\mathcal{N}} \bar{q}) \geq 0$, we can find that $\hat{\eta} > 0$ and thus, $-\hat{\eta}\bar{\varepsilon}^{\mathcal{N}}s''(t^{N*}) \leq 0$. ■

Proof of Corollary 4. We differentiate (iii) w.r.t. γ and α to obtain

$$\partial t^{\mathcal{A}*} / \partial \gamma = -1 / s''(t^{\mathcal{A}*}) < 0 \quad \text{and} \quad \partial t^{\mathcal{A}*} / \partial \alpha = (1 - \beta) / [\bar{\varepsilon}^{\mathcal{N}}s''(t^{\mathcal{A}*})] > 0,$$

where the inequalities follow from $s''(t) > 0$, $\beta < 1$, and $\bar{\varepsilon}^{\mathcal{N}} \geq 0$. ■

Proof of Proposition 4. The retailer does not make any decision and the supplier only makes the promised delivery time decision. We thus start by differentiating $\pi_S^{\mathcal{NF}}(t)$ once and twice w.r.t. t , obtaining

$$\begin{aligned} \frac{\partial \pi_S^{\mathcal{NF}}(t)}{\partial t} &= \left\{ \left[\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] [w - c - s(t) - ts'(t)] - s'(t) [\bar{v} - p] \right\} \frac{M}{\phi \bar{q}}, \\ \frac{\partial^2 \pi_S^{\mathcal{NF}}(t)}{\partial t^2} &= \left\{ -2s'(t) \left[\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] - s''(t) \left[\bar{v} - p + \left(\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right) t \right] \right\} \frac{M}{\phi \bar{q}}. \end{aligned} \quad (\text{iii})$$

The second order condition is satisfied, as discussed in Section 2, because $s'(t) < 0$ and $s''(t) > 0$. Hence, a unique solution exists. ■

Proof of Corollary 5. We differentiate $D^{\mathcal{NF}}$ once w.r.t. p to obtain

$$\frac{\partial D^{\mathcal{NF}}}{\partial p} = \frac{M}{\phi \bar{q}} \left[-\gamma \frac{\partial t^{\mathcal{NF}*}}{\partial p} - 1 + \frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} \frac{\partial t^{\mathcal{NF}*}}{\partial p} \right] < 0,$$

where $\partial t^{\mathcal{NF}*} / \partial p < 0$ because of $s'(t^{\mathcal{NF}*}) < 0$. Differentiating $\pi_S^{\mathcal{NF}}(t^{\mathcal{NF}*})$ once w.r.t. p gives $\partial \pi_S^{\mathcal{NF}}(t^{\mathcal{NF}*}) / \partial p < 0$ as $s'(t^{\mathcal{NF}*}) < 0$ and $s''(t^{\mathcal{NF}*}) > 0$. ■

Proof of Corollary 6. We differentiate (iii) once w.r.t. γ and α to obtain

$$\begin{aligned} \frac{\partial t^{\mathcal{NF}*}}{\partial \gamma} &= - \frac{w - c - s(t^{\mathcal{NF}*}) - t^{\mathcal{NF}*} s'(t^{\mathcal{NF}*})}{s''(t^{\mathcal{NF}*}) \left[\bar{v} - p + \left(\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right) t^{\mathcal{NF}*} \right] + 2s'(t^{\mathcal{NF}*}) \left[\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right]} \leq 0, \\ \frac{\partial t^{\mathcal{NF}*}}{\partial \alpha} &= \frac{(1-\beta) [w - c - s(t^{\mathcal{NF}*}) - t^{\mathcal{NF}*} s'(t^{\mathcal{NF}*})]}{[\alpha(1-\beta) - \gamma \bar{\varepsilon}^{\mathcal{N}}] [2s'(t^{\mathcal{NF}*}) + s''(t^{\mathcal{NF}*}) t^{\mathcal{NF}*}] + s''(t^{\mathcal{NF}*}) (\bar{v} - p) \bar{\varepsilon}^{\mathcal{N}}} \geq 0, \end{aligned}$$

where the inequalities follow from $\bar{\varepsilon}^{\mathcal{N}} \geq 0$ as well as the first and second order conditions. ■

Proof of Corollary 7. A comparison between (10) and (18) indicates that

$$s'(t^{\mathcal{A}*}) = \frac{-2\alpha(t_r - \underline{t}_r)}{k(1-\beta)(t^{\mathcal{A}*})^2} - \gamma < \frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma = s'(t^{\mathcal{N}*}),$$

which means that $t^{\mathcal{N}*} > t^{\mathcal{A}*}$ because $s''(t) \geq 0$. ■

Proof of Corollary 8. We first compare the optimal wholesale price for the case of information disclosure [i.e., $w^{\mathcal{A}*}$ in (12)] and the optimal wholesale price for the case of no information disclosure [i.e., $w^{\mathcal{N}*}$ in (19)]. Using (5), we rewrite $w^{\mathcal{A}*}$ as $w^{\mathcal{A}*} = (\bar{v} + c + s(t^{\mathcal{A}*}) - \gamma t^{\mathcal{A}*})/2 + \alpha(1-\beta)t^{\mathcal{A}*}/(2\bar{\varepsilon}^{\mathcal{A}})$. Comparing the above with $w^{\mathcal{N}*}$ in (19), we have

$$w^{\mathcal{A}*} = w^{\mathcal{N}*} + \frac{1}{2} \left\{ s(t^{\mathcal{A}*}) - s(t^{\mathcal{N}*}) + \alpha(1-\beta) \left[\frac{t^{\mathcal{A}*}}{\bar{\varepsilon}^{\mathcal{A}}} - \frac{t^{\mathcal{N}*}}{\bar{\varepsilon}^{\mathcal{N}}} \right] - \gamma [t^{\mathcal{A}*} - t^{\mathcal{N}*}] \right\}.$$

Moreover, we have

$$w^{\mathcal{A}*} - w^{\mathcal{N}*} = \frac{1}{2} [\Delta u - \Delta s],$$

which is non-negative if and only if the condition in (22) is satisfied.

Next, we compare the optimal retail prices p^{A*} in (13) and p^{N*} in (20). We rewrite p^{A*} as

$$p^{A*} = p^{N*} + \frac{1}{4} \left\{ s(t^{A*}) - s(t^{N*}) + 3\alpha(1 - \beta) \left[\frac{t^{A*}}{\bar{\varepsilon}^A} - \frac{t^{N*}}{\bar{\varepsilon}^N} \right] - 3\gamma [t^{A*} - t^{N*}] \right\}.$$

Therefore,

$$p^{A*} - p^{N*} = \frac{1}{4} [3\Delta u - \Delta s],$$

which is non-negative if and only if the condition in (23) is satisfied. ■

Proof of Corollary 9. Using (4), we re-write D^A in (15) as

$$D^A = \frac{M}{4\bar{q}\phi} \left[\bar{v} - \gamma t^{A*} - c - s(t^{A*}) + \frac{\alpha(1 - \beta)t^{A*}}{\bar{\varepsilon}^A} \right].$$

Noting that D^N is given in (21), we have

$$D^A = D^N + \frac{M}{4\phi\bar{q}} \left\{ s(t^{N*}) - s(t^{A*}) + \alpha(1 - \beta) \left[\frac{t^{A*}}{\bar{\varepsilon}^A} - \frac{t^{N*}}{\bar{\varepsilon}^N} \right] + \gamma [t^{N*} - t^{A*}] \right\}.$$

Thus, if the condition in (24) is satisfied (or, $\Delta u + \Delta s \geq 0$), then $D^A \geq D^N$. Similarly, under the condition in (24), the two firms' expected profits are higher when the information is disclosed. ■

Proof of Proposition 5. We begin by finding the retailer's best responses to a given wholesale price w . We differentiate $\tilde{\pi}_R^A(p, t)$ once and twice w.r.t. p , and have

$$\frac{\partial \tilde{\pi}_R^A(p, t)}{\partial p} = \frac{M[k t(1 - \beta)(w + \bar{v} + \tilde{s}(t) - 2p - \gamma t) + 2\alpha(t_r - \underline{t}_r)]}{k t \bar{q} \phi (1 - \beta)},$$

and $\partial^2 \tilde{\pi}_R^A(p, t) / \partial p^2 = -2M / (\bar{q} \phi)$. Hence, for a given value of t , the optimal retail price maximizing $\tilde{\pi}_R^A(p, t)$ is

$$p^*(w, t) = \frac{k t(1 - \beta)(w + \bar{v} + \tilde{s}(t) - \gamma t) + 2\alpha(t_r - \underline{t}_r)}{2k t(1 - \beta)}.$$

Substituting $p^*(w, t)$ into $\tilde{\pi}_R^A(p, t)$ yields

$$\tilde{\pi}_R^A(w, t) \equiv \tilde{\pi}_R^A(p^*(w, t), t) = \frac{M\eta_1^2}{4t^2\bar{q}\phi}, \text{ where } \eta_1 \equiv \frac{k t(1 - \beta)(\bar{v} - w - \tilde{s}(t) - \gamma t) + 2\alpha(t_r - \underline{t}_r)}{k(1 - \beta)}.$$

Obviously, $\eta_1 > 0$, because, otherwise, her profit is zero. The first- and second-order derivatives of $\tilde{\pi}_R^A(w, t)$ w.r.t. t are

$$\begin{aligned} \frac{\partial \tilde{\pi}_R^A(w, t)}{\partial t} &= - \frac{M[k t^2(1 - \beta)(\tilde{s}'(t) + \gamma) + 2\alpha(t_r - \underline{t}_r)]\eta_1}{2k(1 - \beta)t^3\bar{q}\phi}, \\ \frac{\partial^2 \tilde{\pi}_R^A(w, t)}{\partial t^2} &= - \frac{M[k t^2(1 - \beta)(\tilde{s}'(t) + \gamma) + 2\alpha(t_r - \underline{t}_r)]}{2k(1 - \beta)t^3\bar{q}\phi} \frac{\partial \eta_1}{\partial t} \\ &\quad + \frac{3M[k t^2(1 - \beta)(\tilde{s}'(t) + \gamma) + 2\alpha(t_r - \underline{t}_r)]\eta_1}{2k(1 - \beta)t^4\bar{q}\phi} \\ &\quad - \frac{M[2(\tilde{s}'(t) + \gamma) + t\tilde{s}''(t)]\eta_1}{2t^2\bar{q}\phi}. \end{aligned}$$

We find that, at the value of t satisfying the first order condition $\partial \tilde{\pi}_R^A(w, t) / \partial t = 0$, or, the equation in (25), the second-order derivative $\partial^2 \tilde{\pi}_R^A(w, t) / \partial t^2$ is non-negative when the condition

in (26) is satisfied. That is, under this condition, the optimal promised delivery time (i.e., $\tilde{t}^{A*}$) is uniquely determined by solving the equation in (25) for t .

Next, we find the supplier's optimal wholesale price maximizing $\tilde{\pi}_S^A(w) = (w - c)D^A$. We use $p^*(w, \tilde{t}^{A*})$ to rewrite $\tilde{\pi}_S^A(w)$ as

$$\tilde{\pi}_S^A(w) = \frac{M(w - c)[k\tilde{t}^{A*}(1 - \beta)(\bar{v} - w - \tilde{s}(\tilde{t}^{A*}) - \gamma\tilde{t}^{A*}) + 2\alpha(t_r - \underline{t}_r)]}{2\bar{q}\phi k\tilde{t}^{A*}(1 - \beta)}.$$

Differentiating $\tilde{\pi}_S^A(w)$ once and twice w.r.t. w gives

$$\frac{\partial \tilde{\pi}_S^A(w)}{\partial w} = \frac{M[k\tilde{t}^{A*}(1 - \beta)(\bar{v} + c - \tilde{s}(\tilde{t}^{A*}) - \gamma\tilde{t}^{A*} - 2w) + 2\alpha(t_r - \underline{t}_r)]}{2\bar{q}\phi k\tilde{t}^{A*}(1 - \beta)},$$

and $\partial^2 \tilde{\pi}_S^A(w)/\partial w^2 = -M(\bar{q}\phi) < 0$. Therefore, the optimal wholesale price $\tilde{w}^{A*}$ and the optimal retail price $\tilde{p}^{A*}$ are obtained as in (27). ■

Proof of Corollary A. We differentiate (25) w.r.t. γ and α to obtain

$$\begin{aligned} \frac{\partial \tilde{t}^{A*}}{\partial \gamma} &= -\frac{\tilde{t}^{A*}}{s''(\tilde{t}^{A*})\tilde{t}^{A*} + 2s'(\tilde{t}^{A*}) + 2\gamma} \leq 0, \\ \frac{\partial \tilde{t}^{A*}}{\partial \alpha} &= -\frac{2(t_r - \underline{t}_r)}{k(1 - \beta)\tilde{t}^{A*} [s''(\tilde{t}^{A*})\tilde{t}^{A*} + 2s'(\tilde{t}^{A*}) + 2\gamma]} \leq 0, \end{aligned}$$

where the inequalities follow from the condition in (26). ■

Proof of Proposition 6. The retailer only decides on the promised delivery time. Taking the first- and second-order derivatives of $\tilde{\pi}_R^{AF}(t)$ w.r.t. t , we have

$$\frac{\partial \tilde{\pi}_R^{AF}(t)}{\partial t} = -\tilde{s}'(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] \frac{M}{\phi\bar{q}} + [p - w - \tilde{s}(t)] \left[-\gamma - \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt^2} \right] \frac{M}{\phi\bar{q}}, \quad (\text{iv})$$

$$\begin{aligned} \frac{\partial^2 \tilde{\pi}_R^{AF}(t)}{\partial t^2} &= -2 \left[\tilde{s}'(t)(\bar{v} - 2\gamma t - p) + \gamma(p - w - \tilde{s}(t)) \right] \frac{M}{\phi\bar{q}} \\ &\quad - x\tilde{s}''(t) \left[\bar{v} - \gamma t - p + \frac{2\alpha(t_r - \underline{t}_r)}{(1 - \beta)kt} \right] \frac{M}{\phi\bar{q}}. \end{aligned} \quad (\text{v})$$

We then obtain the first and second order conditions as given in (28) and (29), respectively. ■

Proof of Corollary B. We differentiate the first order condition in (iv) w.r.t. γ and α to obtain

$$\begin{aligned} \frac{\partial \tilde{t}^{AF*}}{\partial \gamma} &= [\tilde{s}'(\tilde{t}^{AF*})\tilde{t}^{AF*} - p + w + \tilde{s}(\tilde{t}^{AF*})] / \tilde{h}(\tilde{t}^{AF*}) \leq 0, \\ \frac{\partial \tilde{t}^{AF*}}{\partial \alpha} &= -\frac{2 [\tilde{s}'(\tilde{t}^{AF*})\tilde{t}^{AF*} + p - w - \tilde{s}(\tilde{t}^{AF*})] (t_r - \underline{t}_r)}{k(1 - \beta) (\tilde{t}^{AF*})^2 \tilde{h}(\tilde{t}^{AF*})} \geq 0, \end{aligned}$$

where

$$\begin{aligned} \tilde{h}(\tilde{t}^{AF*}) &= \tilde{s}''(\tilde{t}^{AF*}) \left[\bar{v} - \gamma\tilde{t}^{AF*} - p + \frac{2\alpha(t_r - \underline{t}_r)}{k(1 - \beta)\tilde{t}^{AF*}} \right] - 2\tilde{s}'(\tilde{t}^{AF*}) \left[\gamma + \frac{2\alpha(t_r - \underline{t}_r)}{k(1 - \beta) (\tilde{t}^{AF*})^2} \right] \\ &\quad - [p - w - \tilde{s}(\tilde{t}^{AF*})] \frac{4\alpha(t_r - \underline{t}_r)}{k(1 - \beta) (\tilde{t}^{AF*})^3} > 0, \end{aligned}$$

and the inequalities follow from the first and second order conditions. ■

Proof of Proposition 7. Differentiating $\tilde{\pi}_R^{\mathcal{N}}(p, t)$ once and twice w.r.t. p yields

$$\frac{\partial \tilde{\pi}_R^{\mathcal{N}}(p, t)}{\partial p} = \frac{M[(\bar{\varepsilon}^{\mathcal{N}})(\bar{v} + w + \tilde{s}(t) - 2p - \gamma t) + \alpha t(1 - \beta)]}{\phi \bar{q} \bar{\varepsilon}^{\mathcal{N}}} \text{ and } \frac{\partial^2 \tilde{\pi}_R^{\mathcal{N}}(p, t)}{\partial p^2} = -\frac{2M}{\phi \bar{q}} < 0.$$

Thus, given the values of promised delivery time t and wholesale price w , the optimal retail price is $p^*(w, t) = [\bar{\varepsilon}^{\mathcal{N}}(\bar{v} + w + \tilde{s}(t) - \gamma t) + \alpha(1 - \beta)t] / (2\bar{\varepsilon}^{\mathcal{N}})$. Substituting $p^*(w, t)$ into $\tilde{\pi}_R^{\mathcal{N}}(p, t)$, we have

$$\partial \tilde{\pi}_R^{\mathcal{N}}(p^*(w, t), t) = \frac{M}{\phi \bar{q}} \eta_2^2, \text{ where } \eta_2 \equiv \frac{(\bar{\varepsilon}^{\mathcal{N}})(\bar{v} - w - \tilde{s}(t) - \gamma t) + \alpha t(1 - \beta)}{2(\bar{\varepsilon}^{\mathcal{N}})},$$

where, obviously, $\eta_2 > 0$. Differentiating the resulting function once and twice w.r.t. t gives

$$\frac{\partial \tilde{\pi}_R^{\mathcal{N}}(p^*(w, t), t)}{\partial t} = \frac{M \eta_2 [-(\bar{\varepsilon}^{\mathcal{N}})(\tilde{s}'(t) + \gamma) + \alpha(1 - \beta)]}{\bar{q} \phi \bar{\varepsilon}^{\mathcal{N}}},$$

and

$$\frac{\partial \tilde{\pi}_R^{\mathcal{N}}(p^*(w, t), t)}{\partial t} = \frac{M [-(\bar{\varepsilon}^{\mathcal{N}})(\tilde{s}'(t) + \gamma) + \alpha(1 - \beta)]}{\bar{q} \phi \bar{\varepsilon}^{\mathcal{N}}} \frac{\partial \eta_2}{\partial t} - \frac{M \eta_2 \tilde{s}''(t)}{\phi \bar{q}},$$

which is negative when the first order condition is satisfied, i.e., $(\bar{\varepsilon}^{\mathcal{N}})(\tilde{s}'(t) + \gamma) = \alpha(1 - \beta)$. Thus, the optimal promised delivery time $\tilde{t}^{\mathcal{N}*}$ is uniquely found by solving the first order condition for t .

Replacing p in $\tilde{\pi}_S^{\mathcal{N}}(w)$ with $p^*(w, t)$, we rewrite the supplier's expected profit function as

$$\tilde{\pi}_S^{\mathcal{N}}(w) = \frac{M(w - c)}{2\phi \bar{q}} \left[\frac{(\bar{\varepsilon}^{\mathcal{N}})(\bar{v} - w - \tilde{s}(\tilde{t}^{\mathcal{N}*}) - \gamma \tilde{t}^{\mathcal{N}*}) + \alpha \tilde{t}^{\mathcal{N}*}(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} \right].$$

The first- and second-order derivatives of $\tilde{\pi}_S^{\mathcal{N}}(w)$ w.r.t. w are computed as

$$\frac{\partial \tilde{\pi}_S^{\mathcal{N}}(w)}{\partial w} = \frac{M[(\bar{\varepsilon}^{\mathcal{N}})(\bar{v} + c - 2w - \tilde{s}(\tilde{t}^{\mathcal{N}*}) - \gamma \tilde{t}^{\mathcal{N}*}) + \alpha \tilde{t}^{\mathcal{N}*}(1 - \beta)]}{2\bar{q} \phi \bar{\varepsilon}^{\mathcal{N}}} \text{ and } \frac{\partial^2 \tilde{\pi}_S^{\mathcal{N}}(w)}{\partial w^2} = -\frac{M}{\phi \bar{q}} < 0.$$

Therefore, we can obtain the optimal wholesale price $\tilde{w}^{\mathcal{N}*}$ and the optimal retail price $\tilde{p}^{\mathcal{N}*} = p^*(\tilde{w}^{\mathcal{N}*}, \tilde{t}^{\mathcal{N}*})$ as in (31). ■

Proof of Corollary C. We differentiate (30) w.r.t. γ and α to obtain

$$\frac{\partial \tilde{t}^{\mathcal{N}*}}{\partial \gamma} = -\frac{1}{\tilde{s}''(\tilde{t}^{\mathcal{N}*})} < 0 \quad \text{and} \quad \frac{\partial \tilde{t}^{\mathcal{N}*}}{\partial \alpha} = \frac{1 - \beta}{\tilde{s}''(\tilde{t}^{\mathcal{N}*}) \bar{\varepsilon}^{\mathcal{N}}} > 0,$$

where the inequalities follow from $\tilde{s}''(\tilde{t}^{\mathcal{N}*}) > 0$. ■

Proof of Proposition 8. The retailer now makes the promised delivery time decision. We thus start by differentiating $\tilde{\pi}_S^{\mathcal{N}\mathcal{F}}(t)$ once and twice w.r.t. t as

$$\begin{aligned} \frac{\partial \tilde{\pi}_S^{\mathcal{N}\mathcal{F}}(t)}{\partial t} &= \left\{ \left[\frac{\alpha(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] [p - w - \tilde{s}(t)] - \tilde{s}'(t) \left[\bar{v} - p - \gamma t + \frac{\alpha(1 - \beta)t}{\bar{\varepsilon}^{\mathcal{N}}} \right] \right\} \frac{M}{\phi \bar{q}}, \\ \frac{\partial^2 \tilde{\pi}_S^{\mathcal{N}\mathcal{F}}(t)}{\partial t^2} &= \left\{ -2\tilde{s}'(t) \left[\frac{\alpha(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] - \tilde{s}''(t) \left[\bar{v} - p + \left(\frac{\alpha(1 - \beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right) t \right] \right\} \frac{M}{\phi \bar{q}}. \end{aligned} \quad (\text{vi})$$

The second order condition is satisfied, as per results in Section 2, because $\tilde{s}'(t) \leq 0$, and $\tilde{s}''(t) \geq 0$. Hence, a unique solution exists. ■

Proof of Corollary D. We differentiate (vi) w.r.t. γ and α to obtain

$$\begin{aligned}\frac{\partial \tilde{t}^{\mathcal{NF}*}}{\partial \gamma} &= -\frac{p - w - \tilde{s}(\tilde{t}^{\mathcal{NF}*}) - \tilde{t}^{\mathcal{NF}*} \tilde{s}'(\tilde{t}^{\mathcal{NF}*})}{\tilde{s}''(\tilde{t}^{\mathcal{NF}*}) \left\{ \bar{v} - p + \left[\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right] \tilde{t}^{\mathcal{NF}*} \right\} + 2\tilde{s}'(\tilde{t}^{\mathcal{NF}*}) \left[\frac{\alpha(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma \right]} \leq 0, \\ \frac{\partial \tilde{t}^{\mathcal{NF}*}}{\partial \alpha} &= \frac{(1-\beta) [p - w - \tilde{s}(\tilde{t}^{\mathcal{NF}*}) - \tilde{t}^{\mathcal{NF}*} \tilde{s}'(\tilde{t}^{\mathcal{NF}*})]}{2\tilde{s}'(\tilde{t}^{\mathcal{NF}*}) [\alpha(1-\beta) - \gamma \bar{\varepsilon}^{\mathcal{N}}] + \tilde{s}''(\tilde{t}^{\mathcal{NF}*}) [\bar{\varepsilon}^{\mathcal{N}} (\bar{v} - p - \gamma \tilde{t}^{\mathcal{NF}*}) + \alpha(1-\beta) \tilde{t}^{\mathcal{NF}*}]} \geq 0,\end{aligned}$$

where the inequalities follow the inequality $\bar{\varepsilon}^{\mathcal{N}} \geq 0$ as well as the first and second order conditions. ■

Proof of Proposition 9. We start with the two retailers' optimal decisions given the supplier's wholesale price w and promised delivery time t . Applying the first order conditions to $\pi_{R1}^{\mathcal{AN}}(p_1)$ and $\pi_{R2}^{\mathcal{AN}}(p_2)$ for p_1 and p_2 , respectively, yields $\partial \pi_{R1}^{\mathcal{AN}}(p_1)/\partial p_1 = 0$ and $\partial \pi_{R2}^{\mathcal{AN}}(p_2)/\partial p_2 = 0$. Differentiating $\pi_{R1}^{\mathcal{AN}}(p_1)$ and $\pi_{R2}^{\mathcal{AN}}(p_2)$ twice w.r.t. p_1 and p_2 gives $\partial^2 \pi_{R1}^{\mathcal{AN}}(p_1)/\partial p_1^2 < 0$ and $\partial^2 \pi_{R2}^{\mathcal{AN}}(p_2)/\partial p_2^2 < 0$. Solving the first order conditions, we obtain the optimal (w, t) -dependent retail prices as $p_1^{\mathcal{AN}*}(w, t)$ and $p_2^{\mathcal{AN}*}(w, t)$. Moreover, we substitute $p_1^{\mathcal{AN}*}(w, t)$ and $p_2^{\mathcal{AN}*}(w, t)$ into the supplier's expected profit function $\pi_S^{\mathcal{AN}}(w, t)$, and maximize the resulting profit to obtain the supplier's optimal decisions. Taking the first- and second-order derivatives of $\pi_S^{\mathcal{AN}}(w, t)$ w.r.t. w , we have

$$\frac{\partial \pi_S^{\mathcal{AN}}(w, t)}{\partial w} = \frac{M\{2\bar{v} + \phi\bar{q} + (2+\phi)[c + s(t) - \gamma t] - 2(2+\phi)w + \alpha(2t_c^{\mathcal{A}} + \phi t_c^{\mathcal{N}})\}}{(4-\phi)\phi\bar{q}},$$

where $\bar{v} = \bar{q}\phi + (1-\phi)q_r$, and $\partial^2 \pi_S^{\mathcal{AN}}(w, t)/\partial w^2 = -2M(2+\phi)/[\phi(4-\phi)\bar{q}] < 0$. Solving the first order condition $\partial \pi_S^{\mathcal{AN}}(w, t)/\partial w = 0$ yields

$$w^{\mathcal{AN}*}(t) = \frac{2\bar{v} + \phi\bar{q} + (2+\phi)[c + s(t) - \gamma t] + \alpha(2t_c^{\mathcal{A}} + \phi t_c^{\mathcal{N}})}{2(2+\phi)}.$$

Then, replacing w with $w^{\mathcal{AN}*}(t)$, we rewrite the supplier's profit function as

$$\pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t) = \frac{M\{2\bar{v} + \phi\bar{q} - (2+\phi)[c + s(t) + \gamma t] + \alpha(2t_c^{\mathcal{A}} + \phi t_c^{\mathcal{N}})\}^2}{4(4-\phi)(2+\phi)\phi\bar{q}}.$$

Differentiating $\pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t)$ once w.r.t. t yields

$$\frac{\partial \pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t)}{\partial t} = \eta_3 \left\{ 2\alpha \frac{\partial t_c^{\mathcal{A}}}{\partial t} + \alpha\phi \frac{\partial t_c^{\mathcal{N}}}{\partial t} - (2+\phi)[s'(t) + \gamma] \right\},$$

where

$$\eta_3 \equiv \frac{M\{2\bar{v} + \phi\bar{q} - (2+\phi)[c + s(t) + \gamma t] + \alpha(2t_c^{\mathcal{A}} + \phi t_c^{\mathcal{N}})\}}{2(4-\phi)(2+\phi)\phi\bar{q}}.$$

Obviously, $\eta_3 \neq 0$ because, otherwise, the supplier's profit is zero. Therefore, the first order condition becomes

$$2\alpha \frac{\partial t_c^{\mathcal{A}}}{\partial t} + \alpha\phi \frac{\partial t_c^{\mathcal{N}}}{\partial t} - (2+\phi)[s'(t) + \gamma] = 0.$$

The second-order derivative of $\pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t)$ is

$$\frac{\partial^2 \pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t)}{\partial t^2} = \eta_3 \left[2\alpha \frac{\partial^2 t_c^A}{\partial t^2} - (2 + \phi) s''(t) \right],$$

where $\eta_3 > 0$. When the value of t satisfies the first order condition and the condition in (34) is satisfied, $\partial^2 \pi_S^{\mathcal{AN}}(w^{\mathcal{AN}*}(t), t) / \partial t^2 \leq 0$. We thus prove the proposition. ■

Proof of Corollary E. According to the condition in (34), we have

$$\frac{8\alpha(t_r - \underline{t}_r)}{k(t^{\mathcal{AN}*})^3(1 - \beta)} - (2 + \phi) s''(t^{\mathcal{AN}*}) < 0. \quad (\text{vii})$$

Moreover, under the condition in (33), we have $s'(t^{\mathcal{AN}*}) + \gamma < 0$ and

$$\frac{4(t_r - \underline{t}_r)}{k(t^{\mathcal{AN}*})^2(1 - \beta)} - \frac{(1 - \beta)\phi}{\bar{\varepsilon}^{\mathcal{N}}} = -\frac{(2 + \phi)[s'(t^{\mathcal{AN}*}) + \gamma]}{\alpha} > 0. \quad (\text{viii})$$

Therefore, we differentiate (33) w.r.t. γ and α to obtain

$$\begin{aligned} \frac{\partial t^{\mathcal{AN}*}}{\partial \gamma} &= \frac{2 + \phi}{8\alpha(t_r - \underline{t}_r) / \left[k(t^{\mathcal{AN}*})^3(1 - \beta) \right] - (2 + \phi) s''(t^{\mathcal{AN}*})} < 0, \\ \frac{\partial t^{\mathcal{AN}*}}{\partial \alpha} &= \frac{4(t_r - \underline{t}_r) / \left[k(t^{\mathcal{AN}*})^2(1 - \beta) \right] - (1 - \beta)\phi / \bar{\varepsilon}^{\mathcal{N}}}{8\alpha(t_r - \underline{t}_r) / \left[k(t^{\mathcal{AN}*})^3(1 - \beta) \right] - (2 + \phi) s''(t^{\mathcal{AN}*})} < 0, \end{aligned}$$

where the inequalities result from (vii) and (viii). ■

Proof of Proposition 10. We start solving $\max_{w,t} [\pi_S^{\mathcal{NB}}(w, t)]^\psi [\pi_R^{\mathcal{NB}}(w, t)]^{1-\psi}$, which is rewritten as

$$\max_{w,t} \left\{ \psi \ln [\pi_S^{\mathcal{NB}}(w, t)] + (1 - \psi) \ln [\pi_R^{\mathcal{NB}}(w, t)] \right\}.$$

Let $G(w, t) = \psi \ln [\pi_S^{\mathcal{NB}}(w, t)] + (1 - \psi) \ln [\pi_R^{\mathcal{NB}}(w, t)]$. Applying the first order conditions to $G(w, t)$ for w and t , respectively, yields

$$\begin{cases} \frac{\partial G(w, t)}{\partial w} = \frac{\psi}{w - c - s(t)} - \frac{2 - \psi}{2y} = 0, \\ \frac{\partial G(w, t)}{\partial t} = \frac{2 - \psi}{y} \frac{\partial y}{\partial t} - \frac{\psi s'(t)}{w - c - s(t)} = 0, \end{cases}$$

where $y = (\bar{v} - w - \gamma t) / 2 + [\alpha(t_r - \underline{t}_r)] / [k(1 - \beta)t]$. The combination of $\partial G(w, t) / \partial w = 0$ and $\partial G(w, t) / \partial t = 0$ gives

$$\begin{cases} k(t^{\mathcal{NB}*})^2(1 - \beta)[s'(t^{\mathcal{NB}*}) + \gamma] + 2\alpha(t_r - \underline{t}_r) = 0, \\ w^{\mathcal{NB}*} = \psi \left[\frac{\bar{v} + c + s(t^{\mathcal{NB}*}) - \gamma t^{\mathcal{NB}*}}{2} + \frac{\alpha(t_r - \underline{t}_r)}{k(1 - \beta)t^{\mathcal{NB}*}} \right] + (1 - \psi)[c + s(t^{\mathcal{NB}*})]. \end{cases}$$

This proves the equations in (35) and (37). Next, to prove that $t^{\mathcal{NB}*}$ and $w^{\mathcal{NB}*}$ are optimal solutions, it is also necessary to prove that $G(w^{\mathcal{NB}*}, t^{\mathcal{NB}*})$ is a joint concave function of $w^{\mathcal{NB}*}$

and $t^{\mathcal{NB}^*}$. To this end, we compute

$$\frac{\partial^2 G(w, t)}{\partial w^2} = -\frac{\psi}{[w - c - s(t)]^2} - \frac{2 - \psi}{4y^2} < 0,$$

and

$$\frac{\partial^2 G(w, t)}{\partial w^2} \frac{\partial^2 G(w, t)}{\partial t^2} - \frac{\partial^2 G(w, t)}{\partial w \partial t} \frac{\partial^2 G(w, t)}{\partial t \partial w} = \frac{\psi s''(t)}{w - c - s(t)} - \frac{2 - \psi}{y} \frac{\partial^2 y}{\partial t^2} \geq 0.$$

We then derive $2[s'(t^{\mathcal{NB}^*}) + \gamma] + t^{\mathcal{NB}^*} s''(t^{\mathcal{NB}^*}) \geq 0$, which proves the equation in (36). Substituting $w^{\mathcal{NB}^*}$ and $t^{\mathcal{NB}^*}$ into $p^{\mathcal{NB}}(w, t)$ yields

$$p^{\mathcal{NB}^*} = \frac{(2 + \psi)(\bar{v} - \gamma t^{\mathcal{NB}^*}) + \psi[c + s(t^{\mathcal{NB}^*})]}{4} + \frac{(2 + \psi)\alpha(t_r - \underline{t}_r)}{2k(1 - \beta)t^{\mathcal{NB}^*}} + \frac{(1 - \psi)[c + s(t^{\mathcal{NB}^*})]}{2},$$

which completes the proof. ■

Proof of Proposition 11. We start with the retailer's optimal decision given the supplier's wholesale price w and promised delivery time t . Differentiating $\pi_R^{\mathcal{N}}(p)$ once and twice w.r.t. p gives $\partial \pi_R^{\mathcal{N}}(p)/\partial p = -2M[\bar{\varepsilon}^{\mathcal{N}}(p - w/2 - \bar{q}/2 + \gamma t/2) - \alpha t(1 - \beta)/2]/(\bar{q}\bar{\varepsilon}^{\mathcal{N}})$ and $\partial^2 \pi_R^{\mathcal{N}}(p)/\partial p^2 = -2M/\bar{q} < 0$. Solving the first order condition $\partial \pi_R^{\mathcal{N}}(p)/\partial p = 0$, we can obtain the optimal (w, t) -dependent retail price as $p^{\mathcal{N}^*}(w, t) = [(w + \bar{q} - \gamma t)\bar{\varepsilon}^{\mathcal{N}} + \alpha t(1 - \beta)]/(2\bar{\varepsilon}^{\mathcal{N}})$.

Next, we substitute $p^{\mathcal{N}^*}(w, t)$ into the supplier's expected profit function $\pi_S^{\mathcal{N}}(w, t)$, and maximize the resulting profit to find the supplier's optimal decisions. Taking the first- and second-order derivatives of $\pi_S^{\mathcal{N}}(w, t)$ w.r.t. w , we have $\partial \pi_S^{\mathcal{N}}(w, t)/\partial w = M[\bar{\varepsilon}^{\mathcal{N}}(c + \bar{q} - 2w - \gamma t) + \bar{\varepsilon}^{\mathcal{N}}s(t) + \alpha t(1 - \beta)]/(2\bar{q}\bar{\varepsilon}^{\mathcal{N}})$ and $\partial^2 \pi_S^{\mathcal{N}}(w, t)/\partial w^2 = -M/\bar{q} < 0$. The optimal t -dependent wholesale price is $w^{\mathcal{N}^*}(t) = [\bar{\varepsilon}^{\mathcal{N}}(c + \bar{q} + s(t) - \gamma t) + \alpha t(1 - \beta)]/(2\bar{\varepsilon}^{\mathcal{N}})$. Replacing $w^{\mathcal{N}^*}(t)$ with w in $\pi_S^{\mathcal{N}}(w, t)$, we obtain $\pi_S^{\mathcal{N}}(w, t) = M[\bar{\varepsilon}^{\mathcal{N}}(c + s(t) + \gamma t - \bar{q}) - \alpha t(1 - \beta)]^2/(8(\bar{\varepsilon}^{\mathcal{N}})^2\bar{q})$. Then, differentiating $\pi_S^{\mathcal{N}}(w^{\mathcal{N}^*}(t), t)$ once and twice w.r.t. t yields

$$\frac{\partial \pi_S^{\mathcal{N}}(w^{\mathcal{N}^*}(t), t)}{\partial t} = \eta_4[\bar{\varepsilon}^{\mathcal{N}}s'(t) + \gamma\bar{\varepsilon}^{\mathcal{N}} - \alpha(1 - \beta)],$$

where

$$\eta_4 \equiv \frac{M[\bar{\varepsilon}^{\mathcal{N}}(c + s(t) + \gamma t - \bar{q}) - \alpha t(1 - \beta)]}{4(\bar{\varepsilon}^{\mathcal{N}})^2\bar{q}}.$$

Noting that $\eta_4 \neq 0$ because, otherwise, $\pi_S^{\mathcal{N}}(w, t) = 0$, we compute

$$\frac{\partial^2 \pi_S^{\mathcal{N}}(w^{\mathcal{N}^*}(t), t)}{\partial t^2} = \frac{\partial \eta_4}{\partial t}[\bar{\varepsilon}^{\mathcal{N}}s'(t) + \gamma\bar{\varepsilon}^{\mathcal{N}} - \alpha(1 - \beta)] + \eta_4\bar{\varepsilon}^{\mathcal{N}}s''(t),$$

which is equal to $\eta_4\bar{\varepsilon}^{\mathcal{N}}s''(t)$ when the first order condition is satisfied. Letting $t^{\mathcal{N}^*}$ satisfy the first order condition $\bar{\varepsilon}^{\mathcal{N}}s'(t) + \gamma\bar{\varepsilon}^{\mathcal{N}} - \alpha(1 - \beta) = 0$, we can find that $\eta_4 < 0$ and thus, $\eta_4\bar{\varepsilon}^{\mathcal{N}}s''(t^{\mathcal{N}^*}) \leq 0$. ■

Proof of Corollary F. When we compare (10) and (39), we find that $s'(t^{\mathcal{A}^*}) < -\gamma < s'(t^{\mathcal{N}^*})$, which means that $t^{\mathcal{N}^*} > t^{\mathcal{A}^*}$ because $s''(t) \geq 0$. ■

Proof of Corollary G. We first compare the optimal wholesale price for the case of information disclosure [i.e., $w^{\mathcal{A}^*}$ in (12)] and the optimal wholesale price for the case of no information disclosure [i.e., $w^{\mathcal{N}^*}$ in (40)]. Using (5), we rewrite $w^{\mathcal{A}^*} = (\bar{v} + c + s(t^{\mathcal{A}^*}) - \gamma t^{\mathcal{A}^*})/2 + \alpha(1 -$

$\beta)t^{\mathcal{A}*}/(2\bar{\varepsilon}^{\mathcal{A}})$. Comparing the above with $w^{\mathcal{N}*}$ in (40), we have

$$w^{\mathcal{A}*} = w^{\mathcal{N}*} + \frac{1}{2} \left\{ s(t^{\mathcal{A}*}) - s(t^{\mathcal{N}*}) + \left[\left(\bar{v} + \frac{\alpha t^{\mathcal{A}*}(1-\beta)}{\bar{\varepsilon}^{\mathcal{A}}} - \gamma t^{\mathcal{A}*} \right) - \left(\bar{q} + \frac{\alpha t^{\mathcal{N}*}(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma t^{\mathcal{N}*} \right) \right] \right\},$$

where the terms to the right of $w^{\mathcal{N}*}$ are non-negative if and only if the condition in (43) is satisfied.

Next, we compare the optimal retail prices $p^{\mathcal{A}*}$ in (13) and $p^{\mathcal{N}*}$ in (41). We rewrite $p^{\mathcal{A}*}$ as

$$p^{\mathcal{A}*} = p^{\mathcal{N}*} + \frac{1}{4} \left\{ (s(t^{\mathcal{A}*}) - s(t^{\mathcal{N}*})) + 3 \left[\left(\bar{v} + \frac{\alpha t^{\mathcal{A}*}(1-\beta)}{\bar{\varepsilon}^{\mathcal{A}}} - \gamma t^{\mathcal{A}*} \right) - \left(\bar{q} + \frac{\alpha t^{\mathcal{N}*}(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma t^{\mathcal{N}*} \right) \right] \right\},$$

where the terms to the right of $p^{\mathcal{N}*}$ are non-negative if and only if the condition in (44) is satisfied.

■

Proof of Corollary H. Using (4), we re-write $D^{\mathcal{A}}$ in (15) as

$$\begin{aligned} D^{\mathcal{A}} &= \frac{M}{2\bar{q}\phi} \left[\frac{\bar{v} - \gamma t^{\mathcal{A}*} - c - s(t^{\mathcal{A}*})}{2} + \frac{\alpha(1-\beta)t^{\mathcal{A}*}}{2\bar{\varepsilon}^{\mathcal{A}}} \right], \\ &> \frac{M}{4\bar{q}} \left[\bar{v} - \gamma t^{\mathcal{A}*} - c - s(t^{\mathcal{A}*}) + \frac{\alpha(1-\beta)t^{\mathcal{A}*}}{\bar{\varepsilon}^{\mathcal{A}}} \right]. \end{aligned}$$

Noting that $D^{\mathcal{N}}$ is given in (42), we have

$$D^{\mathcal{A}} > D^{\mathcal{N}} + \frac{M}{4\bar{q}} \left\{ s(t^{\mathcal{N}*}) - s(t^{\mathcal{A}*}) + \left[\left(\bar{v} + \frac{\alpha(1-\beta)t^{\mathcal{A}*}}{\bar{\varepsilon}^{\mathcal{A}}} - \gamma t^{\mathcal{A}*} \right) - \left(\bar{q} + \frac{\alpha t^{\mathcal{N}*}(1-\beta)}{\bar{\varepsilon}^{\mathcal{N}}} - \gamma t^{\mathcal{N}*} \right) \right] \right\}.$$

Thus, if the condition in (45) is satisfied (namely, $\Delta u + \Delta s \geq 0$), then $D^{\mathcal{A}} \geq D^{\mathcal{N}}$. Similarly, we find that under the condition in (45), the two firms' expected profits are higher when the rating information is disclosed. ■

Online Appendix III Robustness tests

III.1 Results including intercity deliveries

Because the identities of the cities where orders are sourced and delivered are masked, we cannot control for the impact of delivery distance on delivery times. Instead, we drop orders that are fulfilled from a city different from the city of the final destination. To assess the impact of this filtering decision, we first note that same-city orders account for 59% of all transactions and are representative in terms of the main variables (see statistics in Table A in Appendix A). Furthermore, results are similar if we do not filter out inter-city transactions. For example, the relationship between delivery delay and delivery-time rating is as shown in Figure II below and is remarkably similar to the one produced with same-city orders only (see Figure 4 in the main body of our paper). Yet, we prefer to report results with filtered sample to support the internal validity of our results.

III.2 Results addressing price endogeneity

Here we address the potential simultaneity between prices and sales in the empirical test of the implications of the theoretic model. We do so by replicating the regression of $\log(\text{sales})$ on

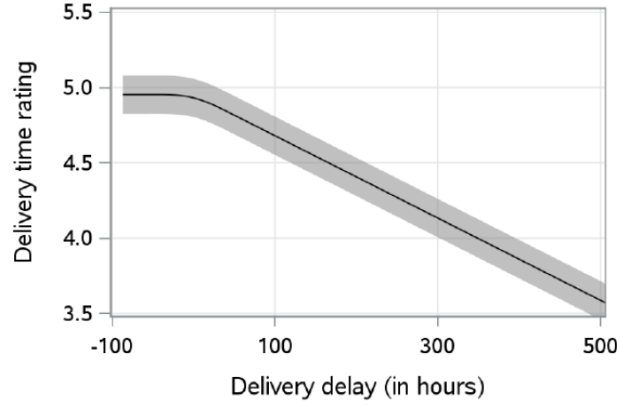


Figure II: Relationship between delivery delay and delivery time ratings for orders within and across cities.

price using two step least squares (2SLS) estimation instead of ordinary least squares (OLS). We compute, for each supplier-subcategory combination, the average price of competing products from other suppliers in the same subcategories. We also compute the number of competing suppliers in each subcategory. We use 3rd order polynomials of these two variables as instruments. Results appear in Table I and are very similar to OLS results. In addition, we estimate a log-log specification to obtain the elasticities of demand with respect to promised delivery time and price. The estimated effect of rating availability on $\log(\text{sales})$ is similar to that obtained with the log-linear model specification.

Table I: Replication of analysis of effect of rating availability on sales using 2SLS.

	<i>Dependent Variable: $\log(\text{sales})$</i>			
	(1)	(2)	(3)	(4)
Avg. price	-0.0004*** (0.0001)	-0.0003*** (0.0001)		
Avg. promised wait	-0.050*** (0.002)	-0.045*** (0.001)		
$\log(\text{Avg. price})$			-0.854*** (0.191)	-0.649*** (0.172)
$\log(\text{Avg. promised wait})$			-5.01*** (0.193)	-4.55*** (0.174)
Rating availability indicator		2.15*** (0.055)		2.17*** (0.058)
Supplier fixed effects	Yes	Yes	Yes	Yes
Subcategory fixed effects	Yes	Yes	Yes	Yes
Observations	7,758	7,758	7,758	7,758
R ²	0.388	0.500	0.360	0.478

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$