Product-Harm Crises and Intermediaries in the Used Car Market

Masahiro Nishida

University of Wisconsin–Madison

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Introduction

Motivation

- Product-harm crises, such as recalls and scandals, have long been studied as negative product-quality information shocks that affect demand and market efficiency
  - Cars have been a good example because recalls are frequently issued
- In used car markets, such a shock reaches households through **dealers**: most household purchases of used cars go through dealers
- A dealer chooses not only the **price** of a car but also **which cars it keeps on its lot**
  - It can sell a car in its inventory to a household at retail or to another dealer in the **interdealer wholesale market**

- **What role does the interdealer wholesale market play in how dealers respond to a demand shock?**

Introduction

Background: Mitsubishi Fuel Economy Scandal

- **April 20, 2016**: Mitsubishi Motors disclosed that it had overstated the fuel economy ratings of four kei car models
  - Kei car: the smallest regulatory class of passenger cars in Japan
- The four models were built by Mitsubishi and sold under both the **Mitsubishi** and the **Nissan** badges
- **No recall**: the cars stayed legal to drive and resell, so the disclosure was a pure information shock to perceived quality



Mitsubishi eK Wagon



Nissan Dayz



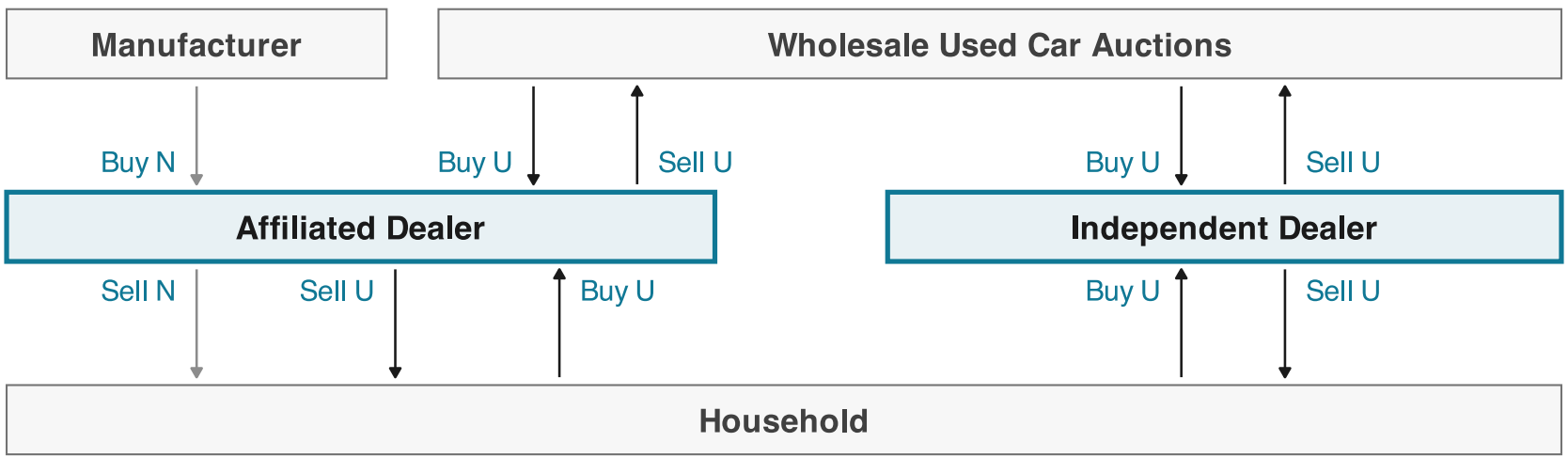
Mitsubishi eK Space



Nissan Dayz Roox

Introduction

Background: Used Car Market and Dealers in Japan



N = new car, U = used car. Buy/Sell: the dealer's action. Arrows: direction the vehicle moves.

- 94% of households' used car purchases go through dealers
- **Affiliated dealers**: franchised new car dealers of a manufacturer; their used cars are mostly own-brand trade-ins
- **Independent dealers**: used car specialists; rely more on auctions

Introduction

Research Questions

1. When a **demand shock** hits, how do dealers adjust their **prices**, and how do **households' purchases** respond?
2. What role does the **interdealer wholesale market** play in these responses?

How I Answer

- **Data**: retail listings (dealer-to-household) and auction records (dealer-to-dealer)
- **Descriptive analysis**: compare wholesale prices, retail prices, and retail sale probabilities of affected vs. unaffected cars, before vs. after the disclosure
- **Model**: build and estimate an equilibrium model that links the retail and wholesale markets
  - Two-period OLG: many dealers enter each period, with or without an endowment
  - They trade cars in the wholesale market, then try to sell to households at retail
  - An unsold car is sold in the next period's wholesale market, and the dealer exits
- **Counterfactuals**: highlight the role of the interdealer wholesale market in these responses

Introduction

Preview of Findings

Descriptive analysis

- **Wholesale prices** of affected cars fall; the unsold rate rises only in the short run
- **Retail prices** fall, and the cut is smaller at Nissan-affiliated than at independent dealers
- The **retail sale probability** rises in the short run and is unchanged in the long run

Model and counterfactuals

- The demand loss is concentrated at **independent** dealers (94.5 thousand JPY vs. none at Nissan-affiliated dealers)
- **Mandatory retail of trade-ins**: independent dealers' retail prices and sale probabilities fall more; the wholesale price response is almost unchanged
- **Segmented wholesale markets**: the wholesale price in independent dealers' market falls much more, and so do their retail prices; Nissan-affiliated dealers no longer cut prices

Introduction

Related Literature

- Intermediaries, search frictions, and market thickness in decentralized markets for durable assets (Gavazza 2011; 2016; Li et al. 2024; 2025; Huang, Luo, and Xia 2019; Murry and Zhou 2020; Gavazza, Lizzeri, and Roketskiy 2014)
  - **This paper**: models the *interdealer wholesale market* explicitly
- Dealer inventories and interdealer trade in financial OTC markets (Duffie, Gârleanu, and Pedersen 2005; Dunne, Hau, and Moore 2015; Colliard, Foucault, and Hoffmann 2021)
  - **This paper**: pass-through in the *dealer-to-customer* vs. the *interdealer* layer
- Product-harm crises (Van Heerde, Helsen, and Dekimpe 2007; Liu and Shankar 2015; Cleeren, Dekimpe, and Van Heerde 2017; Strittmatter and Lechner 2020; Ater and Yoseph 2022; Che, Katayama, and Lee 2023; Bijgaart and Cerruti 2024; Bachmann et al. 2023)
  - **This paper**: follows the damaged products through the intermediation chain
- Used car wholesale auctions as a reallocation technology (Overby and Forman 2015; Subramanian and Overby 2017)
  - **This paper**: how the *organization* of the wholesale market shapes pass-through

Institutional Background

- **April 20, 2016**: Mitsubishi Motors disclosed that it had overstated the fuel economy ratings of four kei car models
- Government retesting found the actual fuel economy **5–16% below the ratings**
  - Before the correction, the ratings were on par with competing kei cars; after it, they were near the bottom of the class
- New car sales of the four models were suspended until June 30, 2016
- Affected units: **468K Nissan-badged** and **157K Mitsubishi-badged** cars built by March 2016
- This paper focuses on the **Nissan-badged** affected models
  - Nissan's reputational damage was small: Mitsubishi's stock price fell by 42% in 3 trading days, Nissan's did not fall
  - Mitsubishi's affiliated dealers stopped selling the affected models as used cars as well as new cars; Nissan's did not

▸ Later disclosures →

Data

Wholesale auto auctions

Dealer-to-dealer

- 83 of about 120 venues, about 70% of auction listings in Japan
- Auction date and venue, sold price (highest bid if unsold), unsold indicator, vehicle characteristics, inspector condition score

Online retail platform (Goo-net)

Dealer-to-household: dealers advertise their inventory

- Monthly snapshots of listings (listing-month panel)
- Listing price, vehicle characteristics, dealer and location, removal date and destination (household, auction, another dealer, …)

- **Sample**: August 2015 – December 2016 (9 months before, 8 after the disclosure); gasoline kei passenger cars, vintages 2013–2016, 500 km to under 100,000 km
- **Affected**: Nissan Dayz and Dayz Roox. **Unaffected**: kei cars of six other automakers
- **Sample size**: 223,120 auction listings (148,860 sold); 163,552 first retail listings

▸ Auction summary → ▸ Retail summary → ▸ Exits →

Descriptive Analysis

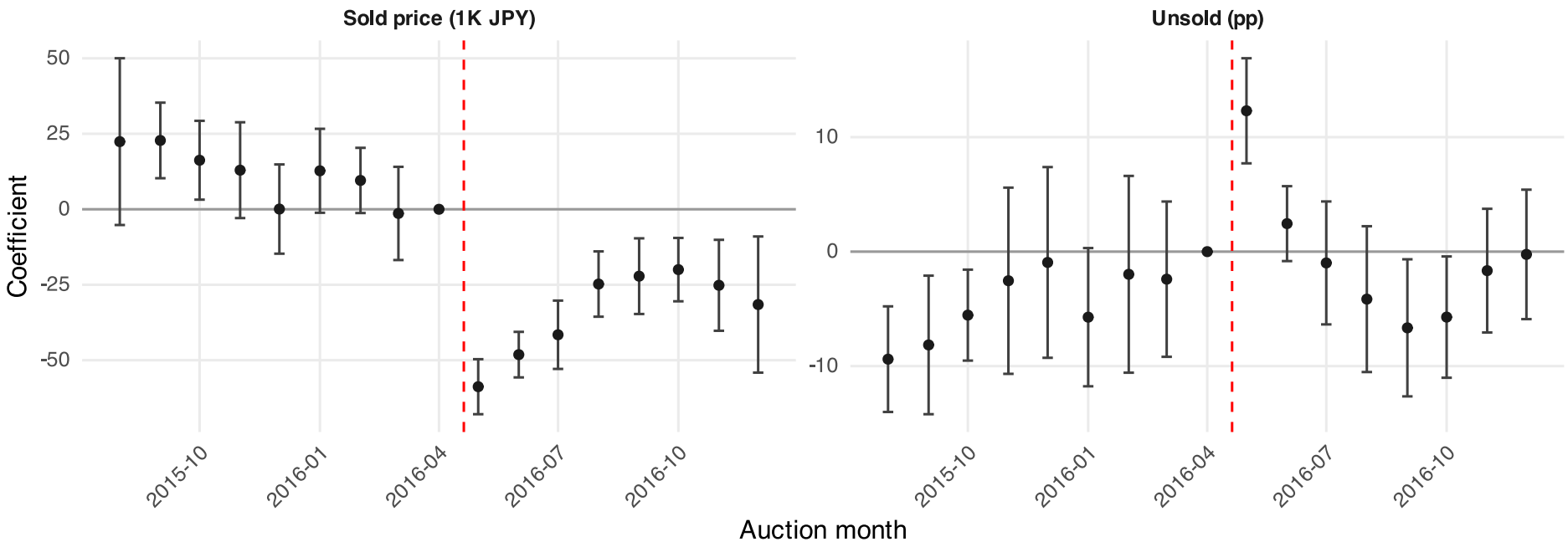
Overview

- Compare the **affected** Nissan models with **unaffected** kei cars of the same vintages, before vs. after April 20, 2016
- **Wholesale**: transaction price, unsold indicator
- **Retail**: first listing price, sale to a household within 3 months of listing
- **Event studies** month by month (reference April 2016) and **pre-post** estimates
  - Short run: May–July 2016; long run: August–December 2016
- **Retail by dealer type**: affected cars at Nissan-affiliated vs. at independent dealers, each against its own pre level; unaffected cars at both types form the comparison group

▸ Specifications →

Descriptive Analysis

Wholesale Auction Prices and Unsold Rates

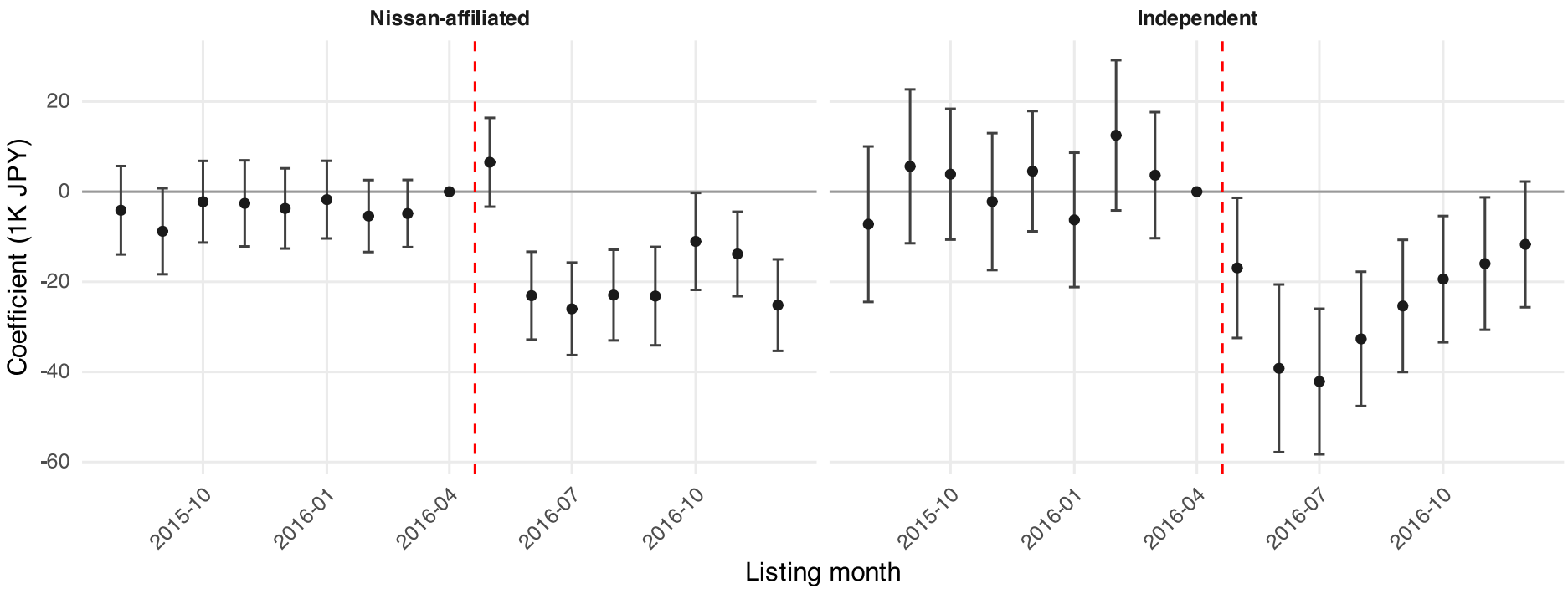


- Pre-post averages: sold price −57.3 (SR) / −33.6 (LR) thousand JPY, about 7% and 4%; unsold rate +7.8 pp (SR) / −0.1 pp (LR)

▸ Pre-post table ⟶

Descriptive Analysis

Retail Listing Prices by Dealer Type



▸ Pooled event study ⟶

Descriptive Analysis

Retail Prices and Sales: Long-Run Changes

	Listing price (1K JPY)		3-month consumer sale (pp)	
	Pooled	By type	Pooled	By type
Affected × Post	−17.05***		−0.77	
	(2.20)		(1.46)	
Affected × Nissan-affiliated × Post		−15.61***		−0.03
		(2.68)		(1.77)
Affected × Independent × Post		−21.60***		−2.48
		(3.45)		(1.93)
N	160,975	160,975	90,102	90,102

Long run: August–December 2016 against the pre period. Controls: repair history, mileage and vehicle-age bins, warranty (price). Fixed effects: listing month, model × grade × vintage, dealer. SEs clustered by dealer; * p < 0.1, ** p < 0.05, *** p < 0.01.

▸ Short run ⟶ ▸ Sale event studies ⟶ ▸ Dealer sale ⟶

Model

Overview

- **OLG model of used car dealers**, who live at most two periods
- Every period a continuum of young dealers enters; each dealer has a **capacity of one car**
  - Some entrants hold an **endowment**, a car such as a trade-in; the rest enter without a car
- **Wholesale stage**: entering dealers buy and sell cars in the wholesale market
  - An endowed dealer keeps or sells its car; a dealer without a car buys one or none
  - A dealer that does not hold a car exits
- **Retail stage**: a dealer that ends up holding a car posts a retail price
  - Each dealer is a **local monopolist** facing a single representative household
  - If the household buys, the dealer exits
  - If not, the dealer sells the car in the next period's wholesale market as an old dealer and exits

Model

Environment

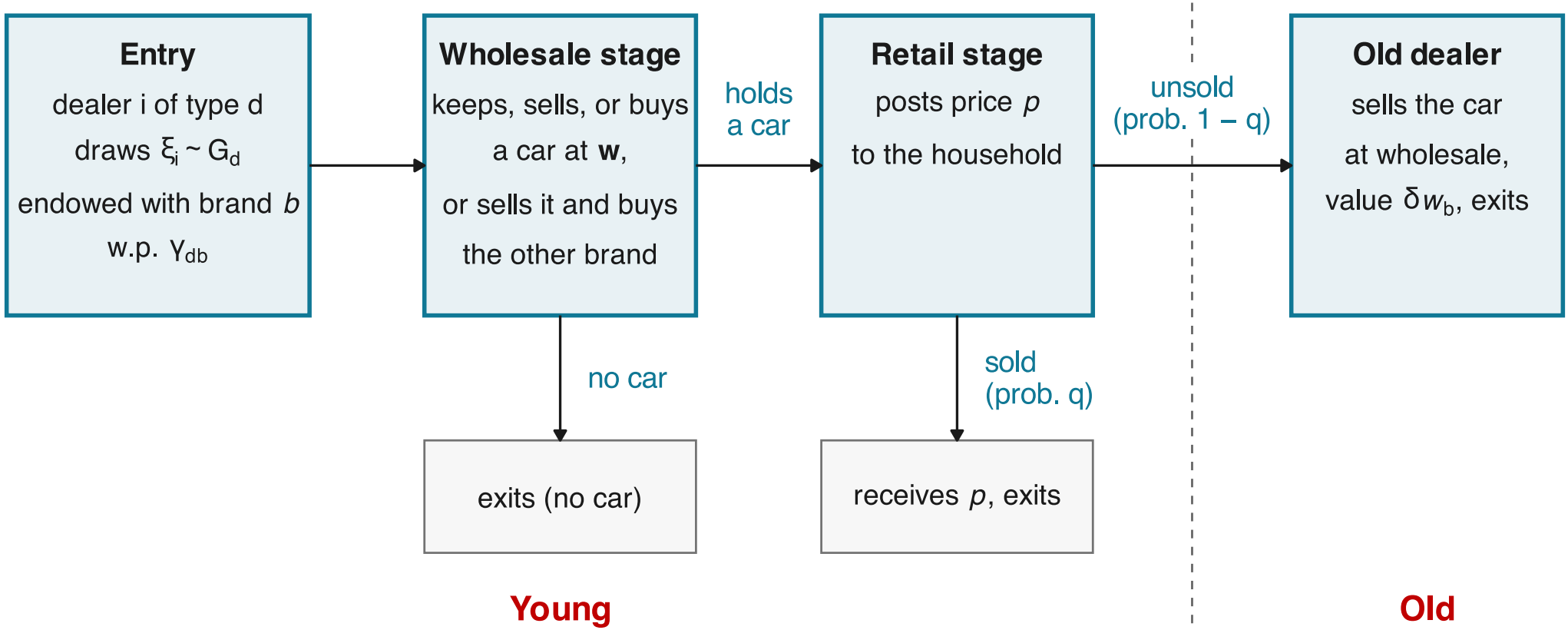
- **Dealer types** $d \in \{N, I, B\}$: Nissan-affiliated, independent, other-brand-affiliated
  - A mass D_d of young dealers of each type enters every period
- **Brands** $b \in \{A, U\}$: affected (Nissan kei models) and unaffected
  - N holds only A, B only U, I either ($\mathcal{J}_N = \{A\}$, $\mathcal{J}_I = \{A, U\}$, $\mathcal{J}_B = \{U\}$)
- **Demand**: on entry, dealer i of type d draws $\xi_i \sim G_d$, the valuation its household attaches to each brand it can hold
- **Endowments (Inflow)**: a mass E_b of brand-b cars enters each period as the endowments of entrants; a type-d entrant is endowed with brand b with probability γ_{db}, independently of demand:

$$\gamma_{NA} D_N + \gamma_{IA} D_I = E_A, \qquad \gamma_{BU} D_B + \gamma_{IU} D_I = E_U$$

- **Wholesale market**: single and competitive; brand b trades at w_b, constant in the stationary state; discount factor δ

Model

Timing



Model

Retail Stage: Pricing

- The household buys at price p iff $u_i = \xi_{ib} - p + \epsilon_i \geq 0$
  - ϵ_i is logistic with scale σ_ϵ, drawn after the price is posted
- **Sale probability** q:

$$q(p; \xi_{ib}) = \Pr[\epsilon_i \geq p - \xi_{ib}] = \Lambda\left(\frac{\xi_{ib} - p}{\sigma_\epsilon}\right)$$

- An unsold car is sold at wholesale next period: liquidation value δw_b

$$V(\xi_{ib}, w_b) = \max_p \{q(p; \xi_{ib})\, p + [1 - q(p; \xi_{ib})]\delta w_b\}$$

- **FOC**:

$$p^* = \delta w_b + \frac{\sigma_\epsilon}{1 - q^*}, \quad q^* = q(p^*; \xi_{ib})$$

Model

Wholesale Stage: Affiliated Dealers

- A Nissan-affiliated entrant, which can hold only brand A, chooses among

$$\text{endowed: } \max\left\{\underbrace{V(\xi_{iA}, w_A)}_{\text{keep}}, \underbrace{w_A}_{\text{sell and exit}}\right\} \qquad \text{without a car: } \max\left\{\underbrace{V(\xi_{iA}, w_A) - w_A}_{\text{buy}}, \underbrace{0}_{\text{exit}}\right\}$$

- An endowed dealer keeps its car iff $V(\xi_{iA}, w_A) \geq w_A$; a dealer without a car buys one iff $V(\xi_{iA}, w_A) - w_A \geq 0$
- Both hold a car iff $\xi_{iA} \geq \bar{\xi}_A(w_A)$, the cutoff defined by $V(\bar{\xi}_A(w_A), w_A) = w_A$
- **Holding share** $h_{NA}(\mathbf{w}) = 1 - G_N(\bar{\xi}_A(w_A))$: the share of Nissan-affiliated entrants that hold a car
- Same for other-brand-affiliated dealers and brand U

Model

Wholesale Stage: Independent Dealers

- Options of an entrant endowed with a car of brand b (b' the other brand) and of one without a car:

$$\text{endowed:} \quad \max\left\{ \underbrace{V(\xi_{ib}, w_b)}_{\text{keep}}, \underbrace{w_b}_{\text{sell and exit}}, \underbrace{w_b - w_{b'} + V(\xi_{ib'}, w_{b'})}_{\text{sell and buy } b'} \right\}$$

$$\text{without a car:} \quad \max\left\{ \underbrace{V(\xi_{iA}, w_A) - w_A}_{\text{buy } A}, \underbrace{V(\xi_{iU}, w_U) - w_U}_{\text{buy } U}, \underbrace{0}_{\text{exit}} \right\}$$

- Policy: hold the brand with the larger net value $V(\xi_{ib}, w_b) - w_b$ if nonnegative, else no car:

$$j_I(\xi_i; \mathbf{w}) = \begin{cases} A \text{ if } V(\xi_{iA}, w_A) - w_A \geq \max\{V(\xi_{iU}, w_U) - w_U, 0\} \\ U \text{ if } V(\xi_{iU}, w_U) - w_U > \max\{V(\xi_{iA}, w_A) - w_A, 0\} \\ \varnothing \text{ otherwise} \end{cases}$$

- Holding shares $h_{IA}(\mathbf{w})$, $h_{IU}(\mathbf{w})$; no car: $h_{I\varnothing}(\mathbf{w}) = G_I(\bar{\xi}_A(w_A), \bar{\xi}_U(w_U))$

Model

Stationary Equilibrium

- Wholesale demand for brand A = cars bought; wholesale supply = endowments sold + cars of old dealers R_A:

$$\underbrace{(1-\gamma_{NA})D_N h_{NA} + (1-\gamma_{IA})D_I h_{IA}}_{\mathcal{D}_A(\mathbf{w})} = \underbrace{\gamma_{NA}D_N(1-h_{NA}) + \gamma_{IA}D_I(1-h_{IA})}_{\text{endowments sold}} + R_A(\mathbf{w})$$

- Old dealers sell every car their household did not buy: $R_A(\mathbf{w}) = N_A(\mathbf{w}) - \Phi_A(\mathbf{w})$, holdings minus household sales
- **Market clearing condition**:

$$\mathcal{D}_A(\mathbf{w}) = \mathcal{S}_A(\mathbf{w}) \Leftrightarrow \underbrace{N_A(\mathbf{w})}_{\text{holdings}} = E_A + R_A(\mathbf{w}) \Leftrightarrow \underbrace{\Phi_A(\mathbf{w})}_{\text{household sales of brand A}} = E_A$$

Stationary equilibrium

A stationary equilibrium is a pair of wholesale prices $\mathbf{w} = (w_A, w_U)$ such that, when every dealer prices by the FOC and chooses its inventory by the policies above, the wholesale market clears for each brand: $\Phi_b(\mathbf{w}) = E_b$ for $b \in \{A, U\}$.

Model

Extension: Holding Cost of an Unsold Car

- The estimated model adds a second dimension of heterogeneity across dealers: the **holding cost** of an unsold car
- A dealer whose car does not sell incurs a cost $c_i \sim H_d$ until the next wholesale market
  - The cost is drawn **after** the inventory choice and paid only if the car does not sell
- **FOC**:

$$p^* = \delta w_b - c_i + \frac{\sigma_\epsilon}{1 - q^*}$$

- Wholesale stage: a dealer values a car at its expected value over the cost, $\overline{V}_d(\xi_{ib}; w_b) = \int V(\xi_{ib}, c; w_b)\, dH_d(c)$; the cutoffs and holding shares are as before with $\overline{V}_d$ in place of V

Estimation

Parameters

- A model period is 3 months; four retail cells (N, A), (I, A), (I, U), (B, U)
- **Demand**: $\xi_{iA} \sim \mathcal{N}(\mu_{NA}, \sigma_A^2)$ for N, $\xi_{iU} \sim \mathcal{N}(\mu_{BU}, \sigma_U^2)$ for B, and bivariate normal for I:

$$\begin{pmatrix} \xi_{iA} \\ \xi_{iU} \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} \mu_{IA} \\ \mu_{IU} \end{pmatrix}, \begin{pmatrix} \sigma_A^2 & \rho\sigma_A\sigma_U \\ \rho\sigma_A\sigma_U & \sigma_U^2 \end{pmatrix} \right)$$

- **Holding cost**: $c_i \sim \mathcal{N}(\mu_g^c, (\sigma_g^c)^2)$, $g \in \{\text{aff}, I\}$ (affiliated or independent)
- **Scandal**: lowers the demand for affected cars to $\xi_{iA} - \lambda_d$, $d \in \{N, I\}$
- **Parameters**: $\theta = (\sigma_\epsilon, \mu_{NA}, \mu_{IA}, \mu_{IU}, \mu_{BU}, \sigma_A, \sigma_U, \mu^c_{\text{aff}}, \sigma^c_{\text{aff}}, \mu^c_I, \sigma^c_I)$ and $\lambda = (\lambda_N, \lambda_I)$
- **Set outside**
  - Dealer mass D_d: all new listings per period (incl. regular cars and older kei cars)
  - Inflow E_b: consumer sales per period (outflow)
  - $\rho = 0.4$ (from within-dealership price correlations across brands), $\delta = 0.98$

▸ Details →

Estimation

Two-Stage Estimation

- **Stage 1**: fit θ to 22 moments of the **pre-scandal** data, which describe the pre-scandal stationary equilibrium; at every candidate, the wholesale prices $\mathbf{w}(\theta)$ are re-solved so that both wholesale markets clear, $\Phi_b(\mathbf{w};\theta) = \hat{E}_b^{\text{pre}}$

$$\min_{\theta} Q(\theta) = \frac{1}{22}\sum_{\ell=1}^{22}\left[\frac{m_\ell(\theta, \mathbf{w}(\theta)) - \hat{m}_\ell}{s_\ell}\right]^2$$

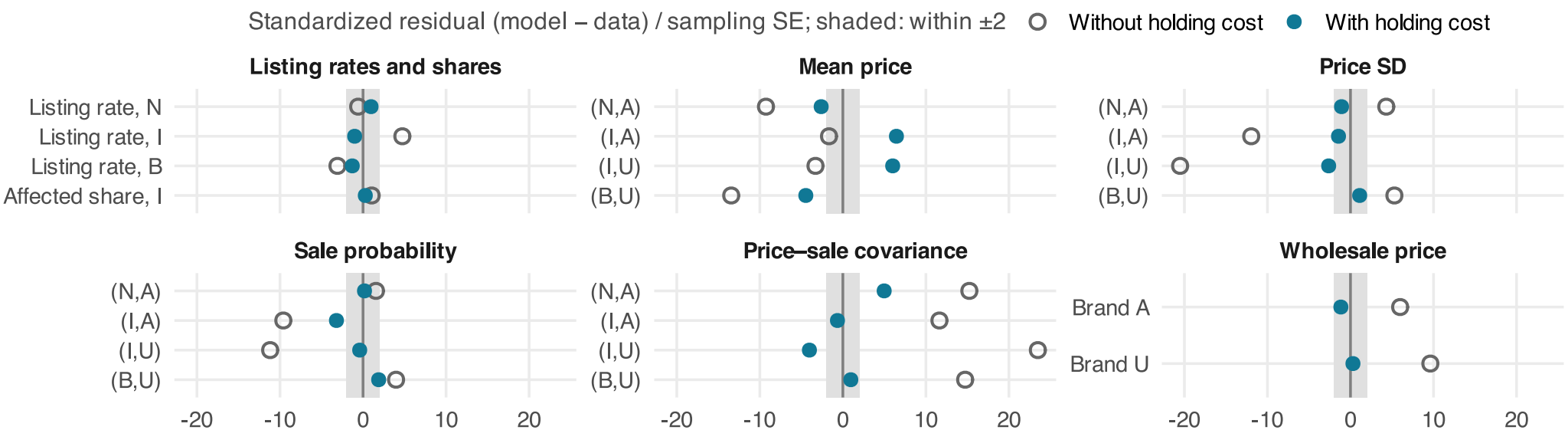
- **Stage 2**: hold $\hat{\theta}$ fixed, add the losses λ, solve the post-scandal equilibrium, and fit λ to five **long-run changes** $\hat{\beta}_\ell$ for affected relative to unaffected cars (retail price and 3-month sale by dealer type; wholesale price)

$$\min_{\lambda} \frac{1}{5}\sum_{\ell=1}^{5}\left[\frac{\Delta m_\ell(\hat{\theta}, \lambda) - \hat{\beta}_\ell}{s_\ell}\right]^2$$

▸ Moments ⟶ ▸ Computation ⟶

Estimation Results

Model Fit: Stage 1



- **Without the holding cost**: misses independents' lower prices and higher sale probabilities and the negative price–sale covariances; **with it**, the fit improves
- The rest of the talk uses the specification with the holding cost

▸ Full table ⟶ ▸ Estimates ⟶

Estimation Results

Model Fit: Stage 2

		Model, with holding cost	
Target	Data	Pre-scandal inflow	Post-scandal inflow
Retail price, Nissan-affiliated (1K JPY)	−15.6 (2.6)	−16.4	−16.6
Retail price, independent (1K JPY)	−21.6 (2.8)	−22.4	−22.5
3-month sale, Nissan-affiliated (pp)	−0.03 (1.69)	0.24	−0.04
3-month sale, independent (pp)	−2.48 (2.01)	−0.40	−0.68
Wholesale price, A − U (1K JPY)	−33.6 (8.0)	−18.8	−17.0

- **Demand losses**: $\hat{\lambda}_N = -4.6$ (11.3) and $\hat{\lambda}_I = 94.5$ (52.7) with the pre-scandal inflow; 11.0 (11.0) and 115.8 (52.9) with the post-scandal inflow

▸ Estimates → ▸ All cases →

Counterfactual Analysis

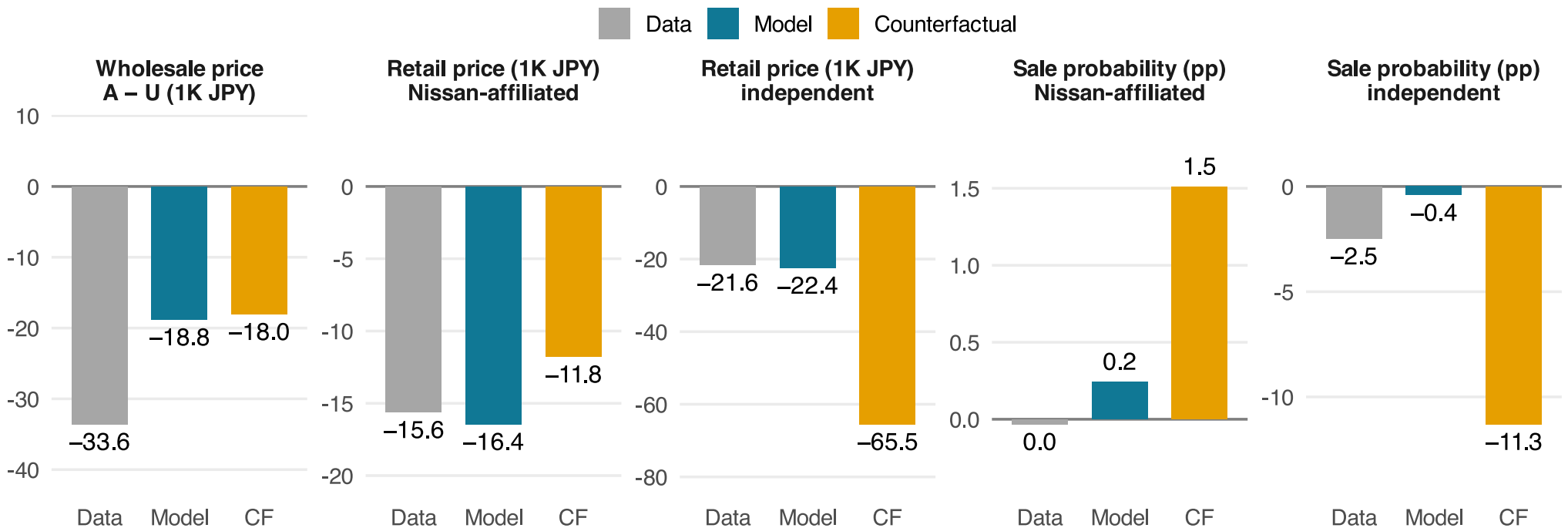
Overview

- **Question**: how does the organization of the wholesale market shape the pass-through of the scandal to retail prices, sale probabilities, and wholesale prices?
- **Scenario 1, mandatory retail of endowments**: an endowed dealer must offer its car at retail; only if the car does not sell does it go to wholesale next period
- **Scenario 2, segmented wholesale markets**: dealers trade only with dealers of their own type
  - Manufacturers run their own auction venues to reallocate used cars across their dealer networks
  - In practice the segmentation is incomplete: affiliated dealers also use other venues, and independent dealers can enter the manufacturers' venues
- Both scenarios assume that $0.7E_b$ is endowed to affiliated dealers and the rest to independent dealers

▸ Venue types ⟶

Counterfactual Analysis

Mandatory Retail of Endowments

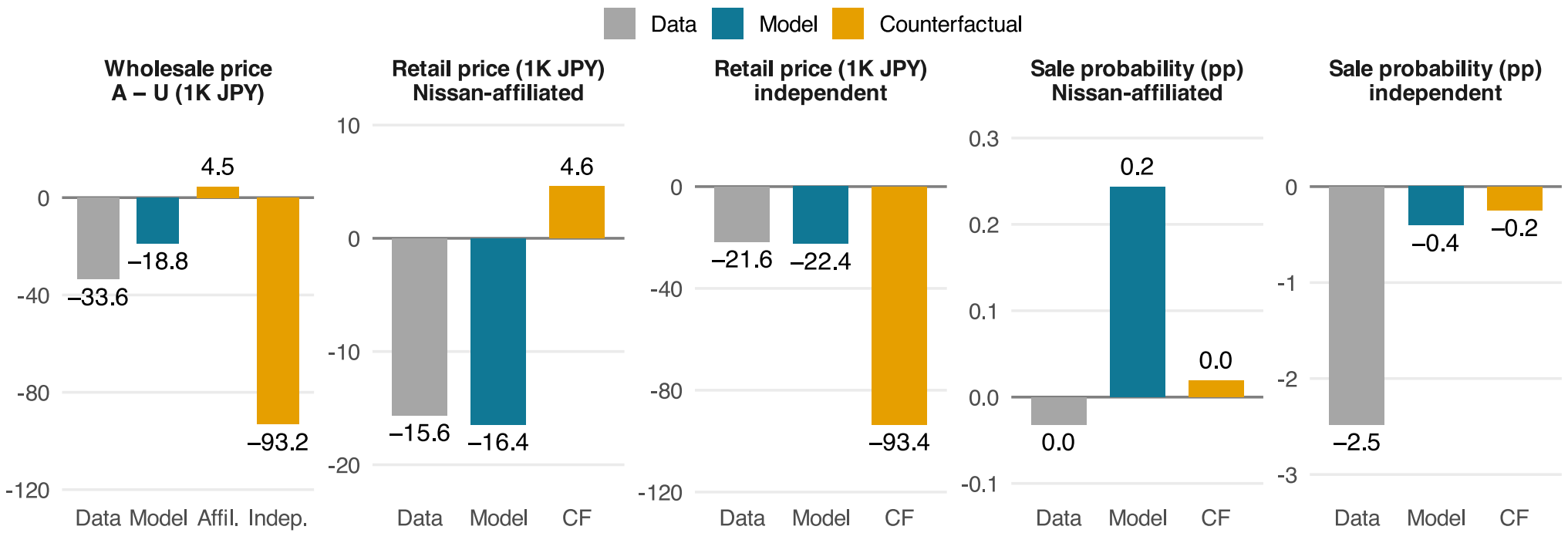


Long-run changes for affected relative to unaffected cars. Model and counterfactual: holding-cost specification, pre-scandal inflow, endowment share ω = 0.7

▸ Post-scandal inflow →

Counterfactual Analysis

Wholesale Markets Segmented by Dealer Type



Long-run changes for affected relative to unaffected cars. Model and counterfactual: holding-cost specification, pre-scandal inflow, endowment share ω = 0.7

▸ Post-scandal inflow →

Conclusion

- **This paper**: how used car dealers respond to a demand shock, the 2016 Mitsubishi fuel economy scandal, and what role the interdealer wholesale market plays
- **Descriptive analysis**: prices of affected cars fell at wholesale and at retail, less at Nissan-affiliated than at independent dealers; sale probabilities changed only in the short run
- **Model**: an OLG model of dealers that links the two markets attributes the shock to a demand loss concentrated at independent dealers
- **Counterfactuals**: the organization of the wholesale market shapes the pass-through: segmenting it by dealer type pulls the two retail responses apart, and mandatory retail of endowments deepens independents' price and sale declines

Appendix

Institutional Details

Later Disclosures: Mitsubishi Regular Cars and Suzuki

- After the disclosure, the transport ministry (MLIT) ordered every manufacturer to review its fuel economy testing; by the May 18, 2016 deadline only Mitsubishi and Suzuki reported irregularities
  - **Mitsubishi** had also used a non-compliant method for most of its regular passenger models; retesting lowered the ratings of eight of them by about 4% on average
  - **Suzuki** had tested 16 models, including kei cars, with methods that deviated from the regulations, but retesting found that every Suzuki model exceeded its registered rating, so its ratings stood and its cars stayed on sale
- Suzuki's disclosure therefore appears to have had little effect on its kei cars, which are part of the comparison group
- No recall in any of these cases: Japanese regulations require recalls only for vehicles that fail to meet the safety standards
- The other Nissan-badged kei models, mostly the Suzuki-built Moco, are excluded from the sample

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Data Details

Summary Statistics: Wholesale Auction Sample

	Pre				Post			
Variable	Mean	P25	P50	P75	Mean	P25	P50	P75
Panel A: Nissan-affected kei								
Transaction price (1K JPY)	898	755	897	1,051	860	693	846	1,037
Unsold (share)	0.325				0.316			
Mileage (1K km)	9.0	3.0	5.0	12.0	15.2	5.0	12.0	21.0
Vehicle age (years)	1.32	1.00	1.00	2.00	1.77	1.00	2.00	2.00
High condition score (share)	0.461				0.271			
Above-middle condition score (share)	0.796				0.754			
Repaired (share)	0.056				0.065			
Venues	72				74			
Observations: listings	10,676				9,890			
Observations: sold listings	7,208				6,768			
Panel B: Unaffected kei								
Transaction price (1K JPY)	882	692	868	1,066	880	678	866	1,074
Unsold (share)	0.361				0.301			
Mileage (1K km)	9.9	2.0	5.0	12.0	16.4	4.0	10.0	23.0
Vehicle age (years)	1.31	1.00	1.00	2.00	1.69	1.00	2.00	3.00
High condition score (share)	0.521				0.352			
Above-middle condition score (share)	0.859				0.789			
Repaired (share)	0.040				0.060			
Venues	76				76			
Observations: listings	111,792				90,762			
Observations: sold listings	71,475				63,409			

▸ ⟵ Back

Data Details

Summary Statistics: Retail First Listings

	Affiliated								Independent							
	Pre				Post				Pre				Post			
Variable	Mean	P25	P50	P75	Mean	P25	P50	P75	Mean	P25	P50	P75	Mean	P25	P50	P75
Panel A: Nissan-affected kei (affiliated = Nissan-affiliated dealers)																
Listing price (1K JPY)	1,201	1,077	1,198	1,334	1,177	1,020	1,188	1,326	1,067	899	1,050	1,213	1,043	891	1,001	1,192
Mileage (1K km)	5.4	2.0	3.0	6.0	9.5	3.0	5.0	12.0	9.6	3.0	6.0	13.0	15.2	5.1	12.0	21.5
Vehicle age (years)	0.97	0.00	1.00	1.00	1.34	1.00	1.00	2.00	1.45	1.00	1.00	2.00	1.83	1.00	2.00	3.00
Listing duration (months)	2.1	1.0	2.0	3.0	2.2	1.0	2.0	3.0	3.2	1.0	2.0	4.0	3.2	1.0	2.0	4.0
Repaired (share)	0.007				0.009				0.170				0.173			
Free warranty (share)	0.986				0.985				0.846				0.871			
Paid warranty (share)	0.005				0.000				0.126				0.072			
Observations	8,199				6,011				2,003				2,387			
Dealers	506				506				795				882			
Panel B: Unaffected kei (affiliated = other-brand-affiliated dealers)																
Listing price (1K JPY)	1,138	950	1,152	1,326	1,143	955	1,159	1,331	1,073	884	1,072	1,273	1,075	874	1,080	1,281
Mileage (1K km)	6.3	2.0	3.9	7.0	8.4	2.6	4.4	9.5	11.7	3.0	7.0	16.0	16.5	4.4	11.8	24.0
Vehicle age (years)	1.05	1.00	1.00	1.00	1.11	0.00	1.00	1.00	1.55	1.00	1.00	2.00	1.84	1.00	2.00	3.00
Listing duration (months)	2.3	1.0	2.0	3.0	2.6	1.0	2.0	3.0	3.2	1.0	2.0	4.0	3.3	1.0	2.0	4.0
Repaired (share)	0.005				0.008				0.128				0.134			
Free warranty (share)	0.991				0.987				0.838				0.843			
Paid warranty (share)	0.004				0.001				0.114				0.094			
Observations	51,343				50,619				19,702				23,288			
Dealers	2,564				2,782				3,345				3,674			

Pre: first listings Aug 2015–Apr 2016; post: May–Dec 2016. Prices in 1K JPY at 2016 prices, mileage in 1K km, duration in months.

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Data Details

Exits of New Listings within 3 and 6 Months

	Affiliated						Independent					
	Pre			Post			Pre			Post		
Vehicle group	N	Sold	Other	N	Sold	Other	N	Sold	Other	N	Sold	Other
Panel A: Exit within 3 months												
Nissan-affected kei	4,103	49.6	37.9	4,086	52.0	36.7	1,551	63.6	9.7	2,430	61.9	12.3
Unaffected kei	17,810	50.2	30.6	23,702	51.0	25.9	14,967	57.6	14.1	23,760	55.5	16.7
Panel B: Exit within 6 months												
Nissan-affected kei	4,103	54.7	42.9	4,085	56.2	41.9	1,551	77.5	13.2	2,428	75.7	14.8
Unaffected kei	17,807	58.7	37.7	23,689	61.0	34.8	14,966	71.5	18.0	23,748	68.4	21.3

N: new listings in the cell. Sold: percent sold to a household within the listing month and the next 2 (Panel A) or 5 (Panel B) months; Other: percent gone to any other destination; the rest are still listed. Sample: dealers that report an exit destination in every month. Pre: cars first listed August 2015 to February 2016; post: May to December 2016.

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Specifications

Event-Study and Pre-Post Specifications

$$Y_i = \sum_{\tau \neq \text{ Apr 2016}} \beta_\tau \, \text{Affected}_i \times \mathbf{1}[t_i = \tau] + X_i'\gamma + \text{FEs} + \varepsilon_i$$

$$Y_i = \beta_{\text{SR}} \, \text{Affected}_i \times \text{PostSR}_{t_i} + \beta_{\text{LR}} \, \text{Affected}_i \times \text{PostLR}_{t_i} + X_i'\gamma + \text{FEs} + \varepsilon_i$$

- **By dealer type**: each affected × post term is split into $\text{Affected}_i \times \text{Affiliated}_i$ and $\text{Affected}_i \times \text{Independent}_i$; the event-study version replaces the post indicators with month indicators
- **Wholesale**: Y_i = transaction price (1K JPY) or unsold × 100; t_i = auction period (20th to 19th, labelled by the month it ends); controls: mileage bins, age bins (0/1/2+), high, middle, and missing condition-score indicators, repair history; fixed effects: auction period, model code × grade × vintage, venue; SEs clustered by model code × vintage
- **Retail price**: Y_i = price at first listing; t_i = month of first listing; controls: mileage bins, age bins, repair history, free and paid warranty; fixed effects: listing month, model code × grade × vintage, dealer; SEs clustered by dealer
- Short run: May–Jul 2016; long run: Aug–Dec 2016; pre: Aug 2015–Apr 2016

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Specifications

Sale Probability: Outcome, Sample, and Weights

- **Outcome**: 1 if a new listing sells to a household within 3 months (gone by the third monthly snapshot after its first one, with a sale to a consumer as its recorded destination), in pp
- **Cohorts**: listings grouped by their first month; short run = May–Jul 2016 entrants, long run = Aug–Dec 2016 entrants; March and April 2016 entrants excluded because their windows straddle the disclosure, so the event study uses **February 2016** as its reference month
- **Sample**: new listings whose dealer records an exit destination in each month of the 3-month window: 92,409 of 147,030 new listings
- **Weights**: within each period, dealer type, and vehicle group, the ratio of all new listings of the car's brand to those in the estimation sample, which corrects for the reporting rates of the brand networks
- **Regression**: the price specifications with the sale dummy, these weights, and the price controls except warranty; the listing price is not a control (jointly determined with the sale); SEs clustered by dealer

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Additional Results

Wholesale Prices and Unsold Rates: Pre-Post

	Sold price (1K JPY)	Unsold (pp)	Log sold price
Affected × Post SR, May–Jul 2016	−57.26***	7.76***	−0.068***
	(7.09)	(2.24)	(0.008)
Affected × Post LR, Aug–Dec 2016	−33.56***	−0.14	−0.038***
	(8.35)	(2.55)	(0.007)
N	148,714	222,999	148,714

Sold price on sold listings with a positive price; unsold (100 if not sold) on all listings. Controls: mileage bins, vehicle-age bins (0/1/2+ years), condition-score indicators, repair history. Fixed effects: auction month, model code × grade × vintage, venue. SEs clustered by model code × vintage in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01. Pre: auction months August 2015 to April 2016.

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Additional Results

Retail Prices and Sales: Pre-Post, Short and Long Run

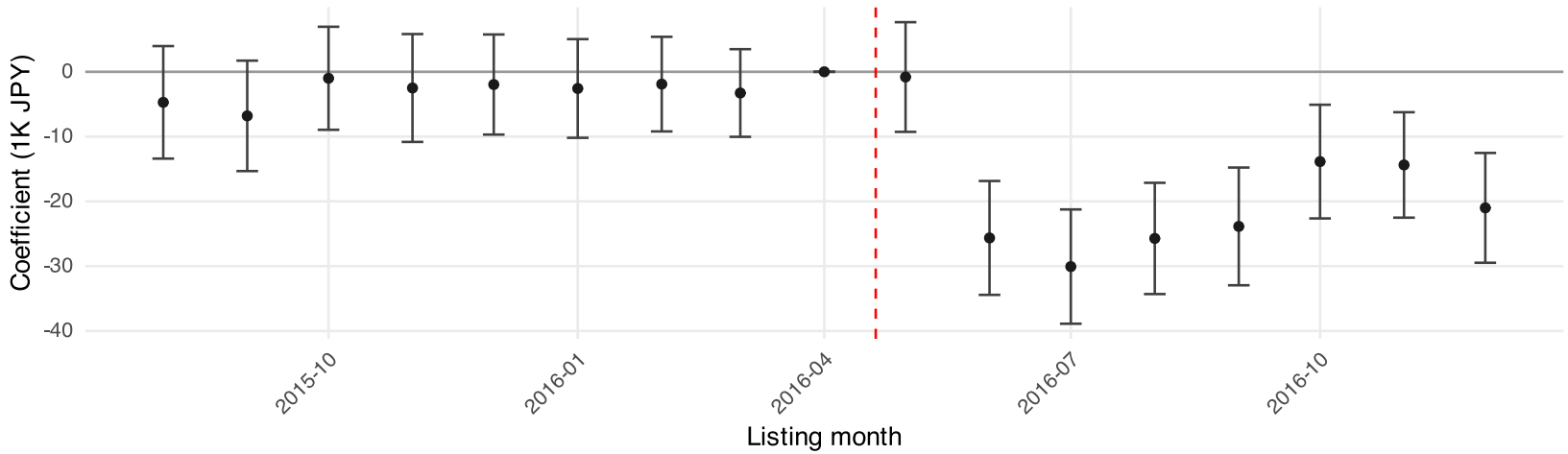
	Listing price (1K JPY)		3-month consumer sale (pp)	
	Pooled	By type	Pooled	By type
Short run, May–Jul 2016				
Affected × Post	−17.49*** (2.60)		5.22*** (1.83)	
Affected × Nissan-affiliated × Post		−12.85*** (3.07)		5.07** (2.22)
Affected × Independent × Post		−33.18*** (4.43)		5.65** (2.22)
Long run, Aug–Dec 2016				
Affected × Post	−17.05*** (2.20)		−0.77 (1.46)	
Affected × Nissan-affiliated × Post		−15.61*** (2.68)		−0.03 (1.77)
Affected × Independent × Post		−21.60*** (3.45)		−2.48 (1.93)
N	160,975	160,975	90,102	90,102

Estimates with SEs clustered by dealer in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01. Price: first listings, pre August 2015 to April 2016. Sale: weighted linear probability model on the new listings of reporting dealers, pre entrants August 2015 to February 2016. Short run: affected cars listed at lower prices and sold more often at both dealer types.

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Additional Results

Retail Listing Prices: Pooled Event Study

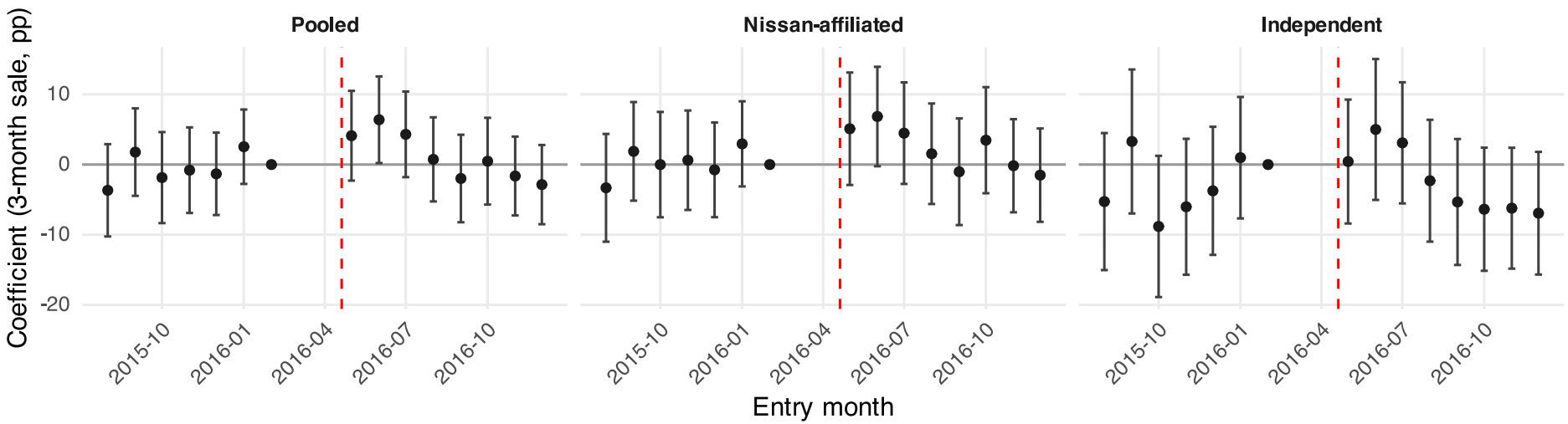


- Listing prices of affected cars are unchanged in May 2016, the first snapshot after the disclosure, fall by 23.9–30.1 thousand JPY from June to September 2016, and remain 13.9–21.0 thousand JPY lower from October to December
- Pre-post: −17.5 (short run) and −17.0 (long run) thousand JPY

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Additional Results

Sale Probability: Event Studies



- Reference month **February 2016**; the March and April 2016 entrants are excluded because their 3-month windows straddle the disclosure
- The pooled series peaks at 6.4 pp for the June 2016 entrants and lies between −2.9 and 0.7 pp from the August entrants on

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Additional Results

3-Month Dealer Sale: Pre-Post

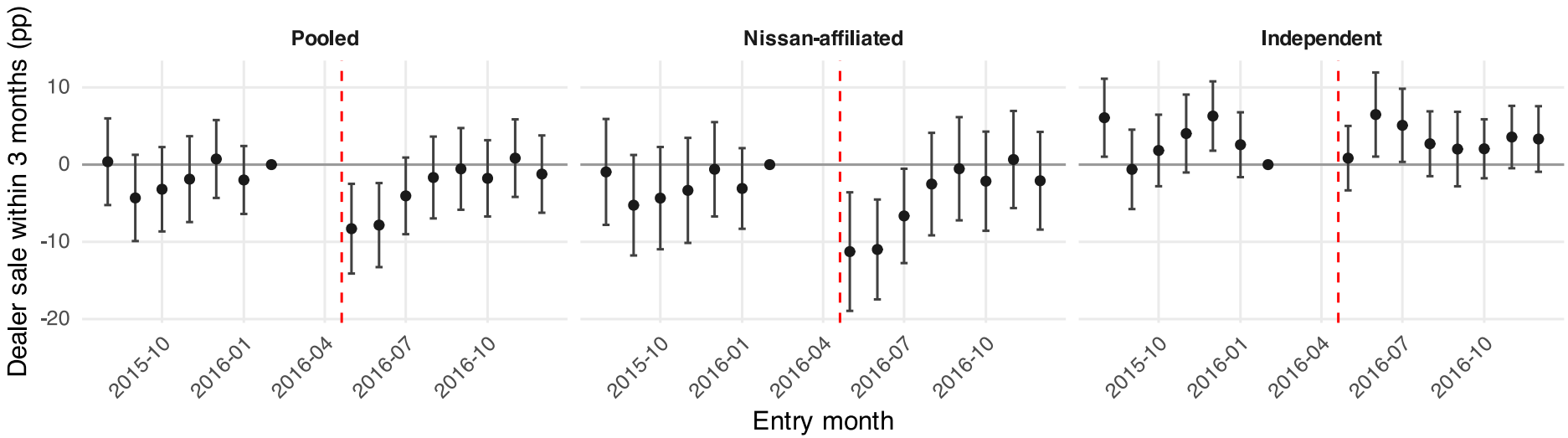
	3-month dealer sale (pp)	
	Pooled	By dealer type
Short run, May–Jul 2016		
Affected × Post	−5.34*** (1.61)	
Affected × Nissan-affiliated × Post		−7.22*** (2.00)
Affected × Independent × Post		0.59 (1.35)
Long run, Aug–Dec 2016		
Affected × Post	0.51 (1.29)	
Affected × Nissan-affiliated × Post		1.15 (1.61)
Affected × Independent × Post		−0.55 (1.13)
N	90,102	90,102

Outcome: 1 if the new listing leaves within the listing month and the next 2 months with a recorded sale at auction, to another dealer, or for export (transfers to another store of the same company are not sales), 0 otherwise, in pp. Same weighted linear probability model, sample, controls, and fixed effects as the consumer sale; SEs clustered by dealer in parentheses; * p < 0.1, ** p < 0.05, *** p < 0.01.

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Additional Results

3-Month Dealer Sale: Event Studies



- Reference month **February 2016**; the March and April 2016 entrants are excluded because their 3-month windows straddle the disclosure
- Dealer sales of affected cars fall by 8.3 and 7.8 pp for the May and June 2016 entrants and lie between −1.8 and 0.8 pp from the August entrants on

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Additional Results

Wholesale Prices by Venue Type

	Sold price (1K JPY)	Unsold (pp)
Affected × NAA × Post SR	−50.72*** (10.11)	14.49*** (5.42)
Affected × NAA × Post LR	−35.81** (13.87)	6.13 (5.96)
Affected × other venues × Post SR	−58.96*** (6.83)	7.57*** (2.35)
Affected × other venues × Post LR	−35.57*** (7.65)	−0.21 (2.75)
NAA − other venues, SR	8.24 (7.81)	6.91 (5.84)
NAA − other venues, LR	−0.23 (9.25)	6.35 (5.90)
NAA × Post SR (unaffected lots)	3.44 (7.06)	−8.17** (3.67)
NAA × Post LR (unaffected lots)	14.81*** (5.60)	−8.49 (5.37)
N	148,714	222,999

NAA is Nissan's auction network. Each affected coefficient compares affected and unaffected lots at the same type of venue; NAA − other is their difference. Specification of the pre-post table otherwise; SEs clustered by model code × vintage. Matching retail listings to later auction sales: of the cars that Nissan-affiliated dealers first listed from April 2015 to March 2017 and sold at auction, 41.0% of the affected and 45.0% of the unaffected cars were sold at NAA.

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Estimation Details

Moments

Moments	Number	Data
Stage 1: pre-scandal equilibrium		
Log listing rates by dealer type	3	All first listings
Affected share of independent dealers' listings	1	All first listings
Initial price means and SDs	4 + 4	All first listings, standardized prices
3-month consumer-sale probabilities	4	Reporting dealers, weighted
Price–sale covariances	4	Reporting dealers, weighted, standardized prices
Wholesale prices	2	Sold lots, standardized prices
Stage 2: long-run changes, affected vs. unaffected		
Retail prices (2), 3-month sales (2), wholesale price (1)	5	Pre-post estimates

▸ ← Back ▸ Price standardization →

Estimation Details

Price Standardization

- In the model, cars of a brand are homogeneous, so each dealer has one price; in the data, prices also depend on age, mileage, repair history, model, grade, vintage, and listing month
- Hedonic regression of the real price, separately for retail and wholesale: age, mileage, and repair-history controls; model–grade–vintage and month fixed effects, and dealership fixed effects at retail; affected-by-month terms (by dealer type at retail) absorb the scandal's price path
- Standardized price $\tilde{p}_i = p_i - \hat{p}_i + \bar{p}$: $\hat{p}_i$ predicts the price from the car's attributes, model–grade–vintage, and month alone (no dealership fixed effect, no affected-by-month terms); $\bar{p}$ is the predicted price of a reference car
- Reference car: the attribute combinations that occur both among first listings and among sold auction lots, weighted by their frequency among first listings, so retail and wholesale standardized prices refer to the same car
- Standardized prices enter the price means, SDs, price–sale covariances, and wholesale prices; the Stage-2 long-run changes use observed prices

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Estimation Details

Externally Set Parameters

- **Dealer mass**: every new listing at a dealership counts as one entering dealer (a car outside the model is the outside option); dealerships whose kei cars are at least 5% of their new listings, excluding the chain that never records destinations; per 3-month period:

$$\hat{D}_d = \frac{3}{17} \sum_{t=\text{ Aug 2015}}^{\text{Dec 2016}} \sum_{i:\, d(i)=d} \mathbf{1}\left\{ \frac{\sum_s K_{is}}{\sum_s A_{is}} \geq 0.05 \right\} A_{it}$$

- **Inflow**: stationary household sales equal the inflow, so $\hat{E}_b^s = \sum_d \hat{N}_{db}^s \, \hat{q}_{db}^s$, new listings per period times their 3-month consumer-sale probability; pre: Aug 2015–Jan 2016 entrants; post: Aug–Dec 2016 entrants
- **Correlation ρ**: 414 independent dealerships with at least three affected and three unaffected listings (Apr 2015–Mar 2016); split-half-corrected correlation of dealership mean residual prices across brands 0.91; scaled by the dealership share of residual variance: $0.91 \times \sqrt{0.50 \times 0.37} = 0.39$ (bootstrap SE 0.02), so $\rho = 0.4$
- **Discount factor**: $\delta = 0.98$ per period (about 8% per year); it enters only through the liquidation value, where it is hard to separate from the holding-cost mean

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Estimation Details

Computation and Acceptance Checks

1. **Cutoffs**: closed form in the baseline; with the holding cost, a safeguarded Newton–bisection method solves $\overline{V}_d(\bar{\xi}_{db}; w_b) = w_b$
2. **Integration**: composite Gauss–Legendre quadrature over the held brand's standardized demand, with panels at the cutoffs (22 nodes per panel; 32 on a check grid); the other brand's demand exactly through the conditional normal CDF; Gauss–Hermite for the holding cost (49 nodes; 65 on the check grid)
3. **Wholesale prices**: damped Newton iteration on $\Phi_A(\mathbf{w}) = E_A$, $\Phi_U(\mathbf{w}) = E_U$ with a finite-difference Jacobian; steps capped at $3\sigma_\epsilon$ and halved until the residuals fall; stop when the scaled residuals fall below 10^{-12}
4. **Parameters**: Stage 1 by L-BFGS-B from four starting values of σ_ϵ (100 to 400 thousand JPY) on a coarse grid, the best refitted on the estimation grid; Stage 2 by BFGS from three starts, which reach the same minimum

- A fit is accepted if the projected gradient of its criterion is below 0.01 and the check grid changes no moment by more than 0.1 sampling SEs; every reported fit passes

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Estimation Details

Stage-1 Estimates

Parameter	Symbol	Without holding cost		With holding cost	
		Estimate	SE	Estimate	SE
Mean demand, affected, Nissan-affiliated	μ_{NA}	468.3	8.5	648.5	19.0
Mean demand, affected, independent	μ_{IA}	27.5	13.0	356.2	30.1
Mean demand, unaffected, independent	μ_{IU}	471.0	5.5	747.1	24.7
Mean demand, unaffected, other-brand-affiliated	μ_{BU}	649.3	3.6	813.3	16.7
Demand SD, affected	σ_A	377.5	4.9	286.9	11.0
Demand SD, unaffected	σ_U	302.8	2.5	200.8	11.5
Household demand scale	σ_ϵ	68.1	1.1	138.1	3.6
Holding-cost mean, affiliated	μ^c_{aff}			72.8	6.3
Holding-cost mean, independent	μ^c_I			160.4	9.6
Holding-cost SD, affiliated	σ^c_{aff}			125.2	4.7
Holding-cost SD, independent	σ^c_I			221.0	6.7

Thousand JPY at 2016 prices. Criterion 110.15 (without holding cost) and 8.05 (with holding cost); 28 and 23 percent of the holding costs of affiliated and independent dealers are negative. SEs map 100 paired multiplier draws of the moments through the Jacobian at the estimates.

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Estimation Details

Stage-2 Estimates

	Pre-scandal inflow	Post-scandal inflow
Without holding cost		
Demand loss, Nissan-affiliated: λ_N	−5.2 (11.1)	19.1 (10.9)
Demand loss, independent: λ_I	92.2 (44.4)	119.1 (43.9)
Criterion Q	0.82	1.09
With holding cost		
Demand loss, Nissan-affiliated: λ_N	−4.6 (11.3)	11.0 (11.0)
Demand loss, independent: λ_I	94.5 (52.7)	115.8 (52.9)
Criterion Q	0.93	1.06

Thousand JPY at 2016 prices; SEs in parentheses map 100 paired multiplier draws of the five targets through the Jacobian, holding the Stage-1 estimates fixed. A negative loss is a gain. Under the pre-scandal inflow the post-scandal equilibrium keeps the inflow at its pre-scandal value; under the post-scandal inflow it uses the measured value.

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Estimation Details

Stage-1 Fit: Listing Rates and Prices

Moment	Data	SE	Without holding cost		With holding cost	
			Model	Residual	Model	Residual
Listing rates and shares						
Log listing rate: Nissan-affiliated	−2.170	0.030	−2.188	−0.58	−2.142	0.97
Log listing rate: Independent	−2.812	0.034	−2.652	4.74	−2.847	−1.01
Log listing rate: Other-brand-affiliated	−1.656	0.025	−1.733	−3.08	−1.688	−1.30
Affected share of independent listings (%)	9.5	0.4	9.9	1.04	9.6	0.27
Mean price (1K JPY)						
Nissan-affiliated / affected	1,146.3	4.6	1,103.7	−9.26	1,134.3	−2.61
Independent / affected	1,083.5	6.2	1,073.2	−1.67	1,123.3	6.45
Independent / unaffected	1,090.6	4.7	1,075.3	−3.30	1,118.6	6.00
Other-brand-affiliated / unaffected	1,134.8	3.1	1,093.7	−13.45	1,121.1	−4.46
Price SD (1K JPY)						
Nissan-affiliated / affected	96.0	1.8	103.9	4.31	94.1	−1.08
Independent / affected	117.7	3.8	72.1	−11.95	112.2	−1.44
Independent / unaffected	115.3	2.3	68.9	−20.52	109.4	−2.63
Other-brand-affiliated / unaffected	82.2	0.8	86.4	5.29	83.0	1.11

Data moments with sampling SEs from 100 paired multiplier draws; residual = (model − data) / SE. Prices are standardized to the reference car, in thousand JPY at 2016 prices.

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Estimation Details

Stage-1 Fit: Sales, Covariances, and Wholesale Prices

Moment	Data	SE	Without holding cost		With holding cost	
			Model	Residual	Model	Residual
3-month consumer-sale probability (%)						
Nissan-affiliated / affected	49.1	1.7	51.7	1.56	49.4	0.18
Independent / affected	63.3	1.8	45.8	−9.60	57.5	−3.20
Independent / unaffected	57.0	1.0	45.8	−11.18	56.6	−0.40
Other-brand-affiliated / unaffected	44.8	1.3	49.8	3.98	47.2	1.88
Price–sale covariance (1K JPY)						
Nissan-affiliated / affected	−9.8	1.8	17.2	15.23	−1.0	4.98
Independent / affected	−10.8	1.9	11.0	11.63	−12.0	−0.65
Independent / unaffected	−9.8	0.9	10.5	23.48	−13.3	−4.03
Other-brand-affiliated / unaffected	−5.1	1.3	13.9	14.73	−3.9	0.96
Wholesale price (1K JPY)						
Affected	931.5	2.4	946.1	5.98	928.7	−1.16
Unaffected	932.2	1.8	949.3	9.62	932.7	0.30

Sale probabilities and covariances use the new listings of reporting dealers, weighted to the badge mix of all first listings. Criterion 110.15 (without holding cost) and 8.05 (with holding cost).

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Estimation Details

Stage-1 Fit: Listing Shares

Moment (%)	Data (SE)	Model	
		Without holding cost	With holding cost
Listing share: Nissan-affiliated	11.4 (0.3)	11.2	11.7
Listing share: Independent	6.0 (0.2)	7.0	5.8
Listing share: Other-brand-affiliated	19.1 (0.5)	17.7	18.5
Affected share of independent dealers' listings	9.5 (0.4)	9.9	9.6

Listing share: the share of the entering dealers of each type that list a car, exp(log listing rate) in percent; its SE is the delta-method transform of the log rate's SE.

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Estimation Details

Stage-2 Fit: Both Specifications and Inflow Cases

			Without holding cost		With holding cost	
Target	Data	SE	Pre	Post	Pre	Post
Model coefficients						
Retail price, Nissan-affiliated (1K JPY)	−15.6	2.6	−16.3	−16.5	−16.4	−16.6
Retail price, independent (1K JPY)	−21.6	2.8	−22.7	−22.7	−22.4	−22.5
3-month sale, Nissan-affiliated (pp)	−0.03	1.69	0.25	−0.42	0.24	−0.04
3-month sale, independent (pp)	−2.48	2.01	−1.13	−1.77	−0.40	−0.68
Wholesale price, A − U (1K JPY)	−33.6	8.0	−18.7	−15.6	−18.8	−17.0
Standardized residuals						
Retail price, Nissan-affiliated			−0.26	−0.34	−0.32	−0.37
Retail price, independent			−0.37	−0.40	−0.30	−0.32
3-month sale, Nissan-affiliated			0.17	−0.23	0.16	0.00
3-month sale, independent			0.67	0.36	1.03	0.90
Wholesale price, A − U			1.85	2.24	1.84	2.06

Pre and Post: the post-scandal equilibrium solved with the pre-scandal or the measured post-scandal inflow. SE: standard deviation of the target over 100 paired multiplier draws, which standardizes the Stage-2 residuals.

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Counterfactual Details

Triple Differences with the Post-Scandal Inflow

Outcome	$\omega = 0.5$	$\omega = 0.7$	$\omega = 0.9$
Mandatory retail of endowments			
Retail price, Nissan-affiliated (1K JPY)	1.25	2.95	4.56
Retail price, independent (1K JPY)	−42.80	−48.13	−42.58
3-month sale, Nissan-affiliated (pp)	0.78	1.03	1.24
3-month sale, independent (pp)	−10.60	−11.90	−10.52
Wholesale price, A − U (1K JPY)	−1.50	−0.59	0.34

Outcome	$\omega = 0.5$	$\omega = 0.7$	$\omega = 0.9$
Segmented wholesale markets			
Retail price, Nissan-affiliated (1K JPY)	22.06	23.20	25.74
Retail price, independent (1K JPY)	−77.25	−74.29	−69.61
3-month sale, Nissan-affiliated (pp)	−0.21	−0.28	−0.40
3-month sale, independent (pp)	0.25	0.12	−0.07
Wholesale, affiliated networks: $w_A^N - w_U^B$	25.67	28.17	30.68
Wholesale, independent market: $w_A^I - w_U^I$	−82.87	−83.76	−85.32

At the shares implied by the baseline, $\omega_A = 0.79$ and $\omega_U = 0.70$ (affiliated dealers' shares of household sales in the baseline pre-scandal equilibrium), the segmented pre-scandal equilibrium coincides with the baseline; there, under the pre-scandal inflow, the triple differences are 21.0 and −71.0 for the retail prices and 23.3 and −74.4 for the wholesale spreads.

▸ ⟵ Mandatory retail ▸ ⟵ Segmentation

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