The Innovation Theory of Information, Value and Mobility

From Lemons and Auctions to Computable Value Circulation in Vehicles, Autonomous Mobility and Robotaxis

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Working Paper
This version: November 11, 2026

Abstract

Markets for used vehicles have served as the canonical illustration of adverse selection for more than half a century, yet the degree of informational asymmetry surrounding an individual vehicle has not, to my knowledge, been made an observable and computable quantity. This paper introduces such a quantity, the *information sufficiency index*, defined as the variance-weighted share of value-relevant uncertainty that available information resolves, and shows that it organizes a wide range of market outcomes. As sufficiency rises, the credible range of value narrows; the probability of trade increases, with a loss-aversion discount that is proportional to residual uncertainty; and market demand shifts upward, raising both the clearing price and the volume of trade. Because information is valuable only if it arrives before a decision is made, the probability of trade is decreasing and convex in response time. Robotaxis, which record their own operation continuously, constitute the limiting case of complete information: the informational friction that impedes the transfer of rights falls to its minimum, and whether such vehicles, which create no driving employment, expand aggregate demand depends on whether an equity index, the share of ownership claims held broadly by households, exceeds an explicit threshold. Every quantity in the framework is computable from a vehicle's identification information and records.

Keywords: information asymmetry; adverse selection; auctions; loss aversion; algorithmic pricing; property rights; equity; autonomous vehicles; robotaxis
JEL classification: D44, D63, D82, D91, E21, L62, R41

*Japox Corporation Co., Ltd., Tokyo, Japan. *Disclosure:* the author is affiliated with Japox Corporation, and the methods described in this paper are the subject of pending patent applications in Japan. Numerical values are illustrative or are estimates quoted from the cited literature; they are not measurements of any product or service. This working paper has not been peer reviewed. Comments are welcome.

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1. Introduction

Used-vehicle prices in Japan are notoriously difficult to read, for sellers and buyers alike. Vehicles of the same model differ widely in value according to grade, equipment, mileage, repair history and the condition of the interior and exterior. The same vehicle, moreover, commands different prices depending on whether it changes hands through a trade-in, a dealer purchase, a dealer auction, retail sale or export, and on where and when the transaction takes place. No single participant can observe all of these determinants, and a substantial informational gap typically separates seller from buyer.

The consequences of such a gap are well understood. Buyers who cannot verify quality shade their offers to allow for uncertainty; owners of vehicles in good condition then decline to sell; the pool of vehicles offered deteriorates; and mutually beneficial trades fail to occur. Akerlof (1970) formalized this mechanism using precisely the example of used cars. More than fifty years later, the mechanism remains visible in the field in the form of prices that participants find hard to interpret.

What has been missing is a way to *measure*, for an individual vehicle, how far the informational gap has been closed. Equilibrium theory characterizes markets in which information is asymmetric, but it does not tell a seller, a buyer or an intermediary how asymmetric the information about *this* vehicle is, nor how much a particular additional piece of information would help. This paper proposes such a measure and develops its consequences.

The central object is the *information sufficiency index*. For each variable relevant to a vehicle's value (attributes identified from its identification number, condition reported or verified, market records, and the context of the transaction) I assign a quality score that reflects how reliable the available information is, and a weight equal to the expected reduction in value variance that observing the variable would bring. The index is the weighted share of value-relevant uncertainty that the available information resolves. It is bounded between zero and one, it is computable from identification information and records, and, as I show, it governs a surprisingly broad set of outcomes.

The paper establishes five results. First, the credible range of value narrows as sufficiency rises (Lemma 1). Second, the probability of trade increases in sufficiency; the discount that buyers apply follows from prospect theory rather than being assumed, and it is proportional to residual uncertainty (Proposition 1). Third, because information is valuable only if it arrives before a decision is taken, the probability of trade is decreasing and convex in response time, so that each second saved is worth most where response is already fast (Proposition 2). Fourth, within a market cell, higher sufficiency shifts demand upward and raises both the market-clearing price and the volume of trade (Proposition 3). Fifth, the robotaxi, a vehicle that records its own operation continuously, represents the limit of complete information. In that limit the informational friction that impedes the transfer of rights falls to its minimum (Proposition 4), and whether vehicles that create no driving employment expand aggregate demand depends on whether an *equity index*, the share of ownership claims held broadly by households, exceeds an explicit threshold (Proposition 5).

The contribution is threefold. Conceptually, the paper converts informational asymmetry from a property of market equilibrium into an observable attribute of an individual asset. Analytically, it links that attribute, within one framework, to the width of value, the probabil-

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ity of trade, timeliness, behavioral discounts, identity utility, channels of value realization, learning agents, the transfer of rights and the distribution of ownership. Practically, every quantity in the framework is computable from a vehicle's identification information and records. The title pays homage to Keynes (1936); the claim, however, is not a general theory of the economy but a computable account, for the concrete case of mobility assets, of the channel through which sufficient information creates trade and the transfer of rights, and through which these in turn create flows of employment and money.

Throughout, a *mobility asset* is any physical object that carries people or goods, including passenger cars, two-wheelers, commercial vehicles, autonomous vehicles, robotaxis and aircraft. The remainder of the paper is organized as follows. Section 2 positions the paper in the literature. Section 3 develops the model. Section 4 describes how the model maps onto the Japanese vehicle market and how its quantities are computed. Section 5 studies the limit of complete information represented by the robotaxi. Section 6 discusses implications, and Section 7 states limitations, testable predictions and conclusions. Proofs are collected in Appendix A.

2. Related literature

Information asymmetry. Akerlof (1970) showed that when only sellers know quality and buyers price at average quality, above-average vehicles withdraw and trade contracts. The analysis established that an informational gap can impair the functioning of a market itself. It concerns, however, the properties of equilibrium; it does not provide a procedure for measuring how far the gap has been closed for an individual vehicle, which is the object of the present paper.

Auctions and disclosure. Wilson (1977) developed a bidding model for objects of common value, and Milgrom and Weber (1982) generalized it to affiliated information. Two implications are central here: bidders shade their bids more when their information is more dispersed, so as to avoid the winner's curse; and a seller's commitment to disclose information raises expected revenue, the linkage principle. Auction design has been implemented in practice, from spectrum allocation to the sale of search advertising analyzed by Edelman et al. (2007). I am not aware, however, of any implementation that measures, within a multi-tier vehicle distribution system such as Japan's, the degree of disclosure for an individual vehicle and reports a range of value accordingly. The information sufficiency index can be read as a measure of disclosure in the sense of the linkage principle.

Behavioral economics. Kahneman and Tversky (1979) showed that outcomes are evaluated as changes relative to a reference point and that losses loom larger than gains. Tversky and Kahneman (1992) estimated the value function, reporting median curvature parameters of 0.88 for gains and losses and a loss-aversion coefficient of 2.25. Andreoni (1990) formalized the satisfaction that individuals derive from their own acts, the warm glow, and Sexton and Sexton (2014) estimated that buyers pay a premium for vehicles whose environmental credentials are visible, with the premium varying by location. These findings imply that the value of a mobility asset depends not only on its physical characteristics but also on how

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losses are perceived and on what ownership signals about the owner. I use them to derive, rather than assume, the discount applied under uncertainty, and to introduce an identity component of value.

Learning agents and algorithmic pricing. Watkins and Dayan (1992) introduced Q-learning, in which the value of actions is updated from the outcomes of trials, and established its convergence. Calvano et al. (2020) showed in simulation that pricing algorithms based on Q-learning can learn to sustain supra-competitive prices without communicating. As bids and prices are increasingly set by software, the information supplied to agents bears on both the efficiency and the *equity* of trade, by which I mean a balance of information, gains and burdens among the parties.

Property rights, transaction costs and distribution. Coase (1960) argued that, absent transaction costs, bargaining allocates a resource to its highest-valued use irrespective of the initial assignment of rights, so that it is transaction costs that govern the allocation of rights. Grossman and Hart (1986) identified ownership with residual rights of control over contingencies that contracts cannot specify. Kaldor (1955) analyzed the relation between income distribution and aggregate demand when the propensity to save out of profits exceeds that out of wages. Together these works show that the ease with which rights are transferred, and the way they are distributed, shape economic outcomes. None, however, provides a procedure for computing, for an individual asset, the informational friction that impedes a transfer of rights, or the effect of the distribution of rights on aggregate demand, from identification information and operating records.

Aggregate demand. Keynes (1936) set out the view that effective demand determines the level of employment, and the multiplier through which a change in spending propagates to aggregate income. I use the multiplier in its simplest form in Section 5.

3. The model

3.1 Environment

A mobility asset i, in the baseline case a used passenger car, carries identification information x_i, such as a vehicle identification number or chassis number. A resolution map R assigns to x_i a set of attributes $a_i = R(x_i)$, including the grade. Let F denote the set of value-relevant variables, partitioned into attributes, condition, market state and transaction context. Only a subset of F is observed for any given asset, and observed variables differ in reliability. The following simplifications are maintained; their limitations are discussed in Section 7.

Assumption 1. Conditional on the available information, the buyer's belief about value is normal.

Assumption 2. Interactions between value-relevant variables are ignored.

Assumption 3. The prospect-theory value function is approximated linearly in each domain.

Assumption 4. Decision deadlines are exponentially distributed.

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3.2 Information sufficiency

For each variable $j \in F$, let $q_{ij} \in [0,1]$ denote its quality for asset i: one if verified, zero if missing, and an intermediate value if self-reported or estimated. Let the weight of variable j be its informativeness, the expected reduction in the variance of value from observing it:

$$w_j = \mathrm{Var}(v) - \mathbb{E}\big[\mathrm{Var}(v \mid z_j)\big]\,. \tag{1}$$

Definition 1. The *information sufficiency index* of asset i is the weighted share of value-relevant uncertainty resolved by the available information:

$$S_i = \frac{\sum_{j \in F} w_j\, q_{ij}}{\sum_{j \in F} w_j}, \qquad 0 \le S_i \le 1. \tag{2}$$

Under Assumption 2, S_i is additive across variables, so that the contribution of any single missing item to the index, and hence to the width of value derived below, can be computed directly.

3.3 The reference value and its range

The buyer does not observe v_i. Given the available information, the buyer's belief has location μ_i and scale σ_i, and the scale contracts as sufficiency rises:

$$\sigma_i = \sigma_{\min} + (\sigma_{\max} - \sigma_{\min})(1 - S_i)^{\gamma}, \qquad \gamma > 0. \tag{3}$$

Here $\sigma_{\max}$ is the scale of uncertainty when nothing is known beyond the market cell and $\sigma_{\min}$ is the irreducible scale that remains under full information. The *reference value* is defined as the median of the belief, chosen for its robustness to extreme transactions. The reported range lies between the α and $1-\alpha$ quantiles; under Assumption 1 its width is

$$W_i = 2\, z_{1-\alpha}\, \sigma_i. \tag{4}$$

Lemma 1. *If $\sigma_{\max} > \sigma_{\min}$ and $S_i < 1$, the width W_i is strictly decreasing in sufficiency S_i.*

3.4 Trade under asymmetric information

The seller knows v_i; the buyer does not. The buyer's use value is $v_i + g$, where $g > 0$ is the gain from trade. The buyer offers expected use value less a discount proportional to the scale of uncertainty,

$$b_i = \mu_i + g - \lambda\, \sigma_i, \tag{5}$$

and the seller accepts whenever $b_i \ge v_i$. Writing $v_i = \mu_i + \sigma_i \varepsilon_i$, with ε_i standard normal from the buyer's perspective, the probability of trade is

$$P_i = \Pr\!\left(\varepsilon_i \le \frac{g}{\sigma_i} - \lambda\right) = \Phi\!\left(\frac{g}{\sigma_i} - \lambda\right). \tag{6}$$

Proposition 1. *The probability of trade P_i is strictly increasing in sufficiency, and the expected forgone gain $g(1 - P_i)$ is strictly decreasing in sufficiency.*

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When information is scarce, trade occurs only for units whose true value lies below the buyer's estimate, so that the units changing hands are adversely selected. Equation (6) is thus a reduced form of the lemons mechanism, with sufficiency as its observable driver.

3.5 Loss aversion and the uncertainty discount

The discount coefficient λ need not be assumed. It follows from the prospect-theory value function

$$\nu(x) = \begin{cases} x^{\alpha} & (x \geq 0), \\ -\lambda_L(-x)^{\beta} & (x < 0), \end{cases} \tag{7}$$

where λ_L is the coefficient of loss aversion. Under Assumption 3 ($\alpha = \beta = 1$), the highest offer the buyer is willing to make sets the expected evaluation of the surplus to zero, and the discount equals $d^*\sigma_i$, where d^* solves

$$d^* = (\lambda_L - 1)\left[\varphi(d^*) - d^*\,\Phi(-d^*)\right]. \tag{8}$$

The coefficient d^* depends on loss aversion alone, and $d^* = 0$ when $\lambda_L = 1$. At the median estimate $\lambda_L = 2.25$ of Tversky and Kahneman (1992), $d^* \approx 0.32$: the representative buyer discounts roughly a third of the scale of uncertainty. A derivation is given in Appendix A. I further conjecture that reporting the reference value together with its range provides seller and buyer with a common reference point, thereby reducing the effective discount.

3.6 Identity utility

Some buyers value what ownership of a particular asset says about them. I therefore add an identity term ι_i to use value:

$$u_i = v_i + g + \iota_i, \qquad \iota_i = \omega_s\, s_i\, vis_i + \omega_e\, e_i\,(vis_i + \rho), \tag{9}$$

where s_i is the status content of the model and grade, e_i its environmental content (for example, an electric or hybrid powertrain), vis_i the visibility of the asset to others, ω_s and ω_e buyer-specific weights, and $\rho \geq 0$ the private satisfaction of owning an environmentally friendly asset even when no one observes it. Identity raises the gain from trade for some buyers, constitutes an independent component of decomposed value, and, because it varies across buyers and places, implies that the reference value of a given asset may differ by region and buyer segment.

3.7 Channels of value realization

A mobility asset can realize value through several channels k: domestic retail, dealer auction, export, parts and material recovery. Each channel has its own location μ_{ik}, its own sufficiency S_{ik} (export markets depend on variables that domestic buyers ignore) and its own cost c_k. Within a channel, value decomposes into the contributions of components z_{im}, and the reconstructed reference value is the maximal net value across channels:

$$\mu_{ik} = \sum_m \beta_{km}\, z_{im}, \qquad v_i^* = \max_k\,(\mu_{ik} - c_k). \tag{10}$$

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Table 1: Illustrative effect of response time on the probability of trade

Response time τ	Share of decisions still open $G(\tau)$	Gain over no information
1 s	98%	+19.7 pp
30 s	61%	+12.1 pp
60 s	37%	+7.4 pp

Notes: Computed from equation (11) with assumed values $\theta = 60$ s and $\Phi_H - \Phi_L = 20$ percentage points (pp). Not a measurement.

The range reported is that of the maximizing channel. Reconstruction reveals value that no single channel displays, as in the case of a vehicle priced low domestically but in demand abroad.

Remark. In common-value auctions, bidders shade more when their information is more dispersed, and disclosure raises expected prices. Because the sufficiency index measures how much has been disclosed and the reference value with its range is a form of public information, the model predicts that dealer-auction prices disperse less around the reference value as sufficiency rises.

3.8 Timeliness of information

Information is valuable only if it arrives before the decision. The decision on asset i is taken before a random deadline D_i: an auction lot closes, a customer leaves the counter, a negotiation ends. If the reference value arrives at response time τ before the deadline, the decision is made at high sufficiency S_H; otherwise it is made at low sufficiency S_L. Let $G(\tau) = \Pr(D_i > \tau)$ denote the share of decisions still open at τ, and $\Phi_H > \Phi_L$ the probabilities of trade at the two levels of sufficiency. Then

$$P(\tau) = G(\tau)\,\Phi_H + [1 - G(\tau)]\,\Phi_L, \qquad G(\tau) = e^{-\tau/\theta}, \tag{11}$$

where the second expression applies under Assumption 4, with mean deadline θ.

Proposition 2. *The probability of trade is strictly decreasing in response time. Under Assumption 4 it is, in addition, strictly convex, so that the marginal value of reducing response time is greatest when response is already fast.*

Table 1 illustrates the magnitudes involved under assumed parameter values.

3.9 Demand and supply in a market cell

Consider a market cell of assets of the same model, grade and year band, with N^B buyers and N^S sellers. A buyer's willingness to pay is $w = \mu + g + \iota - \lambda\sigma(S)$, and a seller's reservation price is v. Demand and supply at price p are

$$D(p) = N^B \Pr(w \geq p), \qquad Q^S(p) = N^S \Pr(v \leq p), \qquad D(p^*) = Q^S(p^*). \tag{12}$$

Proposition 3. *An increase in sufficiency raises every buyer's willingness to pay and shifts demand upward, while supply is unaffected. Consequently, both the market-clearing price p^* and the quantity traded increase.*

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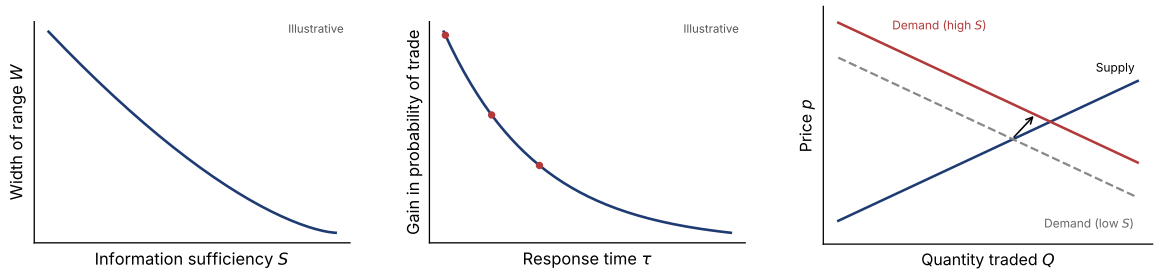


Figure 1: Illustrative relations. Left: the width of the range narrows as sufficiency rises (Lemma 1). Centre: the gain in the probability of trade declines with response time, most steeply at short times; dots mark the entries of Table 1 (Proposition 2). Right: higher sufficiency shifts demand upward along an unchanged supply curve (Proposition 3). Functional forms are examples only.

3.10 Learning agents

Bids and prices are increasingly set by software agents. The Q-function $Q(s, a)$ estimates the long-run return of taking action a (a bid or an asking price) in state s, and is updated with reward r, learning rate η and discount factor δ:

$$Q(s,a) \leftarrow Q(s,a) + \eta \left[r + \delta \max_{a'} Q(s',a') - Q(s,a) \right]. \tag{13}$$

I propose that the state include the reference value m_i, the width W_i, the sufficiency index S_i and the time remaining before the deadline:

$$s = (m_i,\ W_i,\ S_i,\ D_i - \tau)\,. \tag{14}$$

Conjecture 1. *Agents whose state includes the reference value and its range settle on their bids sooner, because a narrower range reduces the variance of rewards to a given action. Because response time enters the state, Proposition 2 carries over to the level of agents.*

Since pricing algorithms can sustain supra-competitive prices without communication (Calvano et al., 2020), the framework requires that the reference value be derived from market data, that it be offered equally to buyers and sellers, and that agent behavior be monitored for signs of coordination.

4. From theory to measurement

4.1 The Japanese vehicle market as a set of variables

Japanese used vehicles flow through a multi-tier sequence of trade-in, purchase, dealer auction, retail and export. I partition value-relevant variables into four groups: attributes identified from identification information (model, grade, year, equipment); condition (mileage, repair history, interior and exterior condition); market state (the distribution of transactions in the same cell, season, exchange rates); and transaction context (channel, region, deadline, buyer segment). Information is not confined to text and numbers: it includes images, video, sound, odor (olfactory information), vibration, temperature and any other sensor output. Quality scores decline in the order of items verified by official documents or images, self-reported

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items, estimated items and unknown items.

4.2 Computation

All quantities in Section 3 are computable from identification information through a sequence of steps: acquisition of the identification information; identification of attributes; generation of variables with quality scores; computation of sufficiency; computation of the reference value and its range; reconstruction across channels; identification of missing information; and output labeled as a reference value. The framework requires only that results be delivered within practical decision times; the means by which this is achieved lie outside the scope of this paper.

5. The limit of complete information: robotaxis

5.1 Generalization across mobility assets

The model extends to any mobility asset that carries identification information and whose value depends on informational asymmetry. For autonomous vehicles, software version, sensor calibration status and over-the-air update history become condition variables; for two-wheelers, modification and storage; for aircraft, flight hours, maintenance records and component times. All are accommodated by the same apparatus of sufficiency, a reference value with its range, and reconstruction across channels.

5.2 Autonomous vehicles and robotaxis

It is useful to distinguish the autonomous vehicle from the robotaxi. An autonomous vehicle is any mobility asset that performs driving operations in place of a human; its value is tied principally to use by its owner. A robotaxi is an autonomous vehicle deployed, without a driver on board, in the business of carrying passengers for a fare; its value is tied principally to revenue from operation, and its operation is recorded continuously.

A robotaxi creates no driving employment directly. It does, however, continuously record its own travel, rides, charging, maintenance and sensor status, so that nearly all value-relevant information is available. If the used car lies at the information-poor end of the spectrum, the robotaxi lies at the information-complete end. Its value is the present value of net operating revenue plus the residual value at retirement,

$$V_i = \sum_{t=1}^{T_i} \delta^t \, n_{it} \, (p_t - c_{it}) + \delta^{T_i} \, v_i^*(T_i), \tag{15}$$

where n_{it} is the quantity of operation in period t, p_t the fare per unit, c_{it} the unit cost (energy, maintenance, cleaning and remote supervision), δ the discount factor, T_i the retirement date and v_i^* the residual value reconstructed by equation (10). As operating records accumulate, quality scores approach one; I assume that sufficiency converges to one as

$$S_i(N) = 1 - [1 - S_i(0)] \, e^{-\kappa N}, \qquad \kappa > 0, \tag{16}$$

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where N is the quantity of accumulated records and κ the rate at which records resolve uncertainty.

5.3 The transfer of rights

Complete information bears directly on the transfer of rights. Consider the transfer of a right in asset i (to own it, to use it, or to receive its revenue) from holder A to holder B, who can put it to more valuable use. Because B discounts for uncertainty as in Section 3, the transfer occurs if and only if

$$V_i^B - V_i^A > c_{tr} + d^* \, \sigma(S_i), \tag{17}$$

where c_{tr} is the cost of the transfer. The right-hand side is the total friction, and its informational component is decreasing in sufficiency.

Proposition 4. *The minimum valuation gap at which a right changes hands is strictly decreasing in sufficiency. In the limit of complete information, the informational component of the friction attains its minimum, $d^*\sigma_{\min}$.*

Assets then migrate, across regions, operators and uses, toward the holders who value them most. In this sense the robotaxi approaches the allocation described by Coase (1960), not by eliminating transaction costs in general, but by minimizing their informational component.

Complete information also makes rights divisible. Let ψ_{hi} denote the share of holder h in asset i and π_i the asset's net revenue per period. Holder h receives

$$y_h = \sum_i \psi_{hi} \, \pi_i, \qquad \sum_h \psi_{hi} = 1, \qquad \pi_i = n_i \, (p - c_i). \tag{18}$$

Because the value of a share can be computed identically by anyone from the operating records, shares can be small and widely held.

5.4 Mobility without driving employment

Each additional robotaxi eliminates driving wages w_d, creates wages w_s in new activities such as maintenance, cleaning, charging and remote supervision, raises the real income of riders by ξ through lower fares, and yields net revenue π to its holders.

Assumption 5. The propensity to consume out of wages and rider gains, c_L, exceeds the propensity to consume out of asset income, c_K, in the spirit of Kaldor (1955).

Definition 2. The *equity index* $E \in [0, 1]$ is the fraction of ownership shares held broadly by households. Equity here denotes a balance of gains and burdens among the parties concerned.

The change in demand from the deployment of M vehicles, and the resulting change in aggregate income under the simple multiplier of Keynes (1936), are

$$\Delta A = M \left[\, c_L \, (w_s - w_d + \xi) + (E \, c_L + (1 - E) \, c_K) \, \pi \, \right], \tag{19}$$

$$\Delta Y = \frac{\Delta A}{1 - c_0}, \qquad E^* = \frac{c_L \, (w_d - w_s - \xi) - c_K \, \pi}{(c_L - c_K) \, \pi}, \tag{20}$$

where c_0 is the economy-wide propensity to consume.

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Proposition 5. *The demand effect ΔA is strictly increasing in the equity index E. For $\pi > 0$, $\Delta A > 0$ if and only if $E > E^*$.*

Whether vehicles that create no driving employment enlarge aggregate demand therefore depends on how evenly ownership of them is held. That balance becomes attainable only when information is complete and rights can be transferred in small units. Demand arising from investment in vehicles and facilities is additional to the effect characterized here.

6. Discussion

By Proposition 3, higher sufficiency raises the number of trades. Each additional trade generates inspection, transport, repair, registration and export activity, and money flows in return. Reconstruction across channels allows vehicles undervalued domestically to realize value through export or as parts, so that value is decomposed, recombined and circulated. Propositions 4 and 5 extend this channel to assets that create no driving employment. Where information is complete, the transfer of rights and the distribution of revenue by shares carry the flow of money alongside the activity that trade generates. The magnitude of circulation therefore depends not only on the number of trades but also on the equity index.

Two implications for the design of information provision follow. First, because pricing agents can coordinate tacitly, information that improves the efficiency of trade should be supplied symmetrically to both sides of the market and accompanied by monitoring. Second, because the circulation effect of complete-information assets hinges on the equity index, the computability of shares is not merely a technical convenience but a condition for the gains from automation to be broadly shared.

7. Limitations and conclusion

The reference value is a reference and differs from realized transaction prices. The model relies on normality, abstracts from interactions between variables, linearizes the value function, assumes exponentially distributed deadlines and represents consumption behavior by two classes. Propositions 4 and 5 are relations that hold within the model; the magnitudes of the coefficients are estimated from records or set by an operator.

The framework yields nine testable predictions:

(a) the reported range narrows as sufficiency rises;

(b) the probability of trade rises with sufficiency;

(c) realized prices concentrate around the reference value;

(d) the probability of trade falls with response time, most steeply at short times;

(e) within a market cell, trading volume rises with sufficiency;

(f) the identity premium differs across regions and buyer segments;

(g) learning agents provided with the reference value and its range settle on their bids sooner;

(h) rights in assets with longer accumulated operating records change hands at smaller valuation gaps;

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(i) the higher the equity index, the larger the increase in consumption from a given deployment of vehicles.

The more sufficient the information, the narrower the range of value, and the more trade, transfer of rights and economic circulation arise. All of this can be computed from the identification information of the asset.

A. Proofs

Proof of Lemma 1. From (3) and (4),

$$\frac{\partial W_i}{\partial S_i} = -2\, z_{1-\alpha}\, (\sigma_{\max} - \sigma_{\min})\, \gamma\, (1 - S_i)^{\gamma - 1} < 0 \tag{21}$$

whenever $\sigma_{\max} > \sigma_{\min}$, $\gamma > 0$, $z_{1-\alpha} > 0$ and $S_i < 1$. □

Proof of Proposition 1. Differentiating (6),

$$\frac{\partial P_i}{\partial S_i} = \varphi\!\left(\frac{g}{\sigma_i} - \lambda\right)\left(-\frac{g}{\sigma_i^2}\right)\frac{\partial \sigma_i}{\partial S_i} > 0, \tag{22}$$

since $\varphi > 0$, $g > 0$ and $\partial \sigma_i / \partial S_i < 0$. The expected forgone gain $g(1 - P_i)$ is then strictly decreasing. □

Derivation of equation (8). Let the buyer offer $b_i = \mu_i + g - d\,\sigma_i$. The buyer's surplus is $x = v_i + g - b_i = \sigma_i(d + \varepsilon_i)$. Under the linear value function with loss aversion, $\mathbb{E}[\nu(x)] = \mathbb{E}[x] + (\lambda_L - 1)\,\mathbb{E}[\min(x, 0)]$. Since $\mathbb{E}[x] = d\sigma_i$ and $\mathbb{E}[\min(d + \varepsilon, 0)] = -[\varphi(d) - d\,\Phi(-d)]$ for standard normal ε, setting $\mathbb{E}[\nu(x)] = 0$ yields (8). Numerically, $\lambda_L = 2.25$ gives $d^* = 0.3227$. □

Proof of Proposition 2. Differentiating (11),

$$P'(\tau) = G'(\tau)\,(\Phi_H - \Phi_L) < 0, \qquad P''(\tau) = \frac{1}{\theta^2}\, e^{-\tau/\theta}\,(\Phi_H - \Phi_L) > 0, \tag{23}$$

since G is strictly decreasing and $\Phi_H > \Phi_L$; the second expression uses Assumption 4. □

Proof of Proposition 3. An increase in sufficiency lowers $\sigma(S)$ and raises every buyer's willingness to pay w by λ times the reduction in σ, so $D(p)$ increases at every p. Supply $Q^S(p)$ is increasing in p and does not depend on S. Hence the intersection moves up along the supply curve, raising both p^* and the quantity traded. □

Proof of Proposition 4. The right-hand side of (17) is $c_{tr} + d^*\sigma(S_i)$, which is strictly decreasing in S_i by (3). As $S_i \to 1$, $\sigma(S_i) \to \sigma_{\min}$. □

Proof of Proposition 5. From (19), $\partial \Delta A / \partial E = M(c_L - c_K)\pi > 0$ under Assumption 5 and $\pi > 0$. Solving $\Delta A > 0$ for E gives $E > E^*$ with E^* as in (20). □

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