(In)efficiency in Information Acquisition and Aggregation through Prices

Alessandro Pavan, Savitar Sundaresan, and Xavier Vives

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Motivation

- Historical **decline in cost of acquiring** and processing information
  - improvements in information technology
  - Nordhaus (2015), Gao and Huang 2020, Goldstein, Yang, and Zuo (2020)
- **Social value unclear**, in particular when it comes to **financial trading**
- Policy debate on how to boost efficiency of financial transactions
  - "sand in the wheels"
  - Tobin taxes (*ad-valorem*)
  - subsides to information acquisition
  - disclosure regulations

This Paper

- Model of competition in schedules
  - **endogenous private information**
  - (partial) information aggregation
- (In)efficiency in
  - financial trading
  - information acquisition
- Policy analysis

Key Results

- Inefficiency (in trading and information acquisition) originates in
  - **learning** externality
  - **pecuniary** externality
- Efficiency in trading does not guarantee efficiency in information acquisition
- Impossibility to induce efficiency in both trading and info acquisition through policies contingent on
  - price
  - individual volume of trade
- Taxes/subsidies need to condition on
  - expenses on info acquisition (when verifiable)
  - **aggregate volume of trade**
- Ad-valorem taxes should not be used

Related Literature (Incomplete)

- **Inefficiency in usage (exogenous info):** Palfrey (1985), Vives (1988), Angeletos and Pavan (2007), Amador and Weill (2012), Myatt and Wallace (2012), Vives (2019),...
- **Inefficiency in info acquisition:** Hellwig and Veldkamp (2009), Colombo, Femminis and Pavan (2014, 2024), Angeletos, Iovino, and La'O (2020), Angeletos and Sastry (2023), Herbert and Lao (2023), ...
- **Info acquisition in financial markets:** Grossman and Stiglitz (1980), Verrecchia (1982), Peress (2010), Manzano and Vives (2011), Kacperczyk, Van Nieuwerburgh, and Veldkamp (2016), Davila and Parlatore (2019), Mondria et al. (2021),...
- **Impact of reduction in cost of information on financial trading:** Peress (2005), Farboodi, Matray, and Veldkamp (2018), Azamsa (2019), Kacperczyk, Nosal and Stevens (2019), Malikov (2019), Mihet (2018),...
- **Correlated/biases in info collection:** Woodford (2012), Nimark and Sundaresan (2019), Frydman and Jin (2020)...
- **Taxing financial transactions**: Tobin (1978), Stiglitz (1989), Sorensen (2017), Dow and Rahi (2000), Colliard and Hoffmann (2017), Cipriani et al. (2022), Davila and Walther (2021), ...

Plan

- Model
- Inefficiency in Trading
- Inefficiency in Information Acquisition
- Policy
- Conclusions

Model

Demand Side

- Unit continuum of traders, $i \in [0, 1]$
- **Limit orders** for homogeneous, perfectly divisible asset
  - more than 50% of NYSE transactions (Li, Ye, and Zheng 2023)
- Individual "demands" schedules:

$$x_i = X_i(p; s_i)$$

Demand Side

- Trader i's payoff:

$$\pi_i = \left(\underbrace{\theta}_{\text{common value}} - \underbrace{p}_{\text{price}} \right) \cdot \underbrace{x_i}_{\text{demand of } i} - \underbrace{\lambda \frac{x_i^2}{2}}_{\text{trading cost}}$$

Supply Side

- Exogenous (inverse) aggregate "supply" schedule:

$$p = \alpha - u + \beta\tilde{x}$$

where $\tilde{x} = \int x_i di$

- Cost

$$\left(\underbrace{\alpha - u}_{\text{opportunity cost}}\right) \cdot \underbrace{\tilde{x}}_{\text{aggregate supply}} + \underbrace{\beta\frac{\tilde{x}^2}{2}}_{\text{trading cost}}$$

- **Price-elastic supply**
  - central banks' operations
  - liquidity auctions
  - noise traders

Information

- θ and u not observable by traders when submitting limit orders
- Information collected by trader i prior to trading:

$$s_i = \theta + \epsilon_i = \theta + f(\underbrace{y_i}_{\text{effort}})(\underbrace{\eta}_{\text{common}} + \underbrace{e_i}_{\text{idiosyncratic}})$$

- Information acquisition: $y_i \in \mathbb{R}_+$, with $f' < 0$
  - cost: $\mathcal{C}(y_i)$, with $\mathcal{C}', \mathcal{C}'' > 0$
  - E.g.,: $\mathcal{C}(y) = By^2/2$, $f(y_i) = 1/\sqrt{y_i}$
- $(\theta, u, \eta, (e_i)_{i\in[0,1]})$ jointly Normal, mean 0, independent

Timing

- $t = 0$: traders acquire information (choose y_i)
- $t = 1$: traders observe private signals s_i and submit limit orders $x_i(\cdot; s_i)$
- $t = 2$: market clears, trades implemented, payoffs

Inefficiency in Trading

Equilibrium Use of Information

Given s_i, trader i submits limit orders summarized in demand schedule $X_i(\cdot, s_i)$ with

$$X_i(p; s_i) \in \arg\max_{x_i} \mathbb{E}\left[(\theta - p)\, x_i - \lambda \frac{x_i^2}{2} | s_i, p\right]$$

Affine equilibrium:

$$X_i(p; s_i) = a s_i + b - c p$$

Equilibrium Use of Information

- Fix precision of private information: $y_i = y$, all i

Proposition.

Unique affine equilibrium.

Sensitivity $a^* > 0$ to private information:

$$a^* = \frac{1}{\lambda} \frac{K(\tau_\omega(a^*))}{\Lambda(\tau_\omega(a^*))}$$

where $\tau_\omega(a)$ is precision of **endogenous signal** contained in eq. price.

Sensitivity to price $c^* = C(a^*)$ and average volume of trade $b^* = B(a^*)$ can be positive or negative

Welfare and Planner's Problem

- Ex-post welfare:

$$W \equiv \underbrace{\int_0^1 \left(\theta x_i - \frac{\lambda}{2} x_i^2\right) di}_{\text{Trader Welfare}} - \underbrace{\left(\alpha - u + \beta \frac{\tilde{x}}{2}\right) \tilde{x}}_{\text{Cost of Supply}}$$

- Planner maximizes W by choosing affine demand schedules $X_i(p; s_i) = a^T s_i + b^T - c^T p$

- Cannot transfer information across traders

Efficient Use of Information

- Fix precision of private information: $y_i = y$, all i

Proposition.

Efficient sensitivity to private information:

$$a^T = \frac{1}{\lambda} \frac{K(\tau_\omega(a^T))}{\Lambda(\tau_\omega(a^T)) + \Xi(a^T) + \Delta(a^T)}$$

Given a^T, $c^T = C(a^T)$ and $b^T = B(a^T)$ pinned down by same conditions as in eq.

- Equilibrium differs from efficient allocation because
  - **learning** externality: $\Delta(a^T) < 0$
  - **pecuniary** externality: $\Xi(a^T) > 0$

Externalities

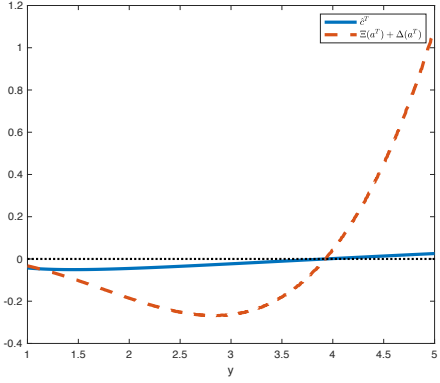
- **Learning externality**
  - traders do not internalize value of price informativeness to other traders
  - inefficiently low sensitivity of eq. schedules to private info
- **Pecuniary externality**
  - traders do not internalize that their response to private information moves prices in non-fundamental manner, affecting other traders' demands through dependence of their limit orders on prices
  - over-sensitivity to private info
  - isolated by looking at "curse economy" in which agents do not learn from prices but endowed with exogenous public signal of same precision as eq. price
  - difference from other pecuniary externalities: originates in dispersed info and endogenous beliefs

Externalities and slope of efficient schedules

- **Learning externality > Pecuniary externality**
  - efficient schedules: upward sloping
- **Pecuniary externality > Learning externality**
  - efficient schedules downward sloping

Impact of Information Quality

- As quality of information y increases:
  - pecuniary externality $\Xi(a^T)$ increases
  - non-monotonic effect on learning externality $\Delta(a^T)$.



Policy Inducing Efficient Trading

Proposition

Efficiency in trading induced by (non-linear) tax

$$T(x_i, p) = \underbrace{\frac{\delta}{2}x_i^2 - t_0 x_i}_{\text{linear-quadratic tax on volume}} + \underbrace{t_p p x_i}_{\text{ad-valorem tax}}$$

- **quadratic tax on volume**, $\frac{\delta}{2}x_i^2$: efficient sensitivity to private info, a^T
- **ad-valorem tax,** $t_p p x_i$: efficient sensitivity to price, c^T
- **linear tax/subsidy on volume,** $t_0 x_i$: efficient ex-ante trade volume, b^T

Inefficiency in Information Acquisition

Equilibrium Acquisition of Private Information

Proposition

There exist $K \in \mathbb{R}_+$ and $J : \mathbb{R}_+ \to \mathbb{R}$ s.t. equilibrium exists (and is unique in affine strategies) if

- $\mathcal{C}'(0) < K$
- $\frac{3}{2y}\mathcal{C}'(y) + \mathcal{C}''(y) > J(y)$

- First condition: $\exists!\ y^*$ s.t. net marginal benefit of more precise information

$$\left.\frac{\partial V^{\#}(y^*, y_i)}{\partial y_i}\right|_{y_i = y^*} = 0$$

  where $V(y, y_i) \equiv \sup_{g(\cdot)} \{\mathbb{E}[\pi_i(y, y_i; g(\cdot))] - \mathcal{C}(y_i)\}$, with $g(\cdot)$ representing trading strategy.

- Second condition: $V(y, y_i)$ strictly quasi-concave in y_i

Inefficiency of Information Acquisition under Efficient Trading

- y^T: efficient quality of private information

Proposition

Suppose traders forced to trade efficiently (given y^T)

- downward-sloping efficient schedules ($\Xi(a^T) > \Delta(a^T)$): traders **over-invest** in information
- upward-sloping efficient schedules ($\Xi(a^T) < \Delta(a^T)$): : traders **under-invest** in information

- Efficiency in trading does not guarantee efficiency in acquisition

Inefficiency of Information Acquisition under Efficient Trading

- **Downward-sloping efficient schedules**
  - pecuniary externality $>$ learning externality
  - planner forces agents to respond less to private info ($a^T < a^*$)
  - agents over-invest in information ($y^* > y^T$)
- **Upward-sloping efficient schedules**
  - learning externality $>$ pecuniary externality
  - planner forces agents to respond more to private info ($a^T > a^*$)
  - agents under-invest in information ($y^* < y^T$)

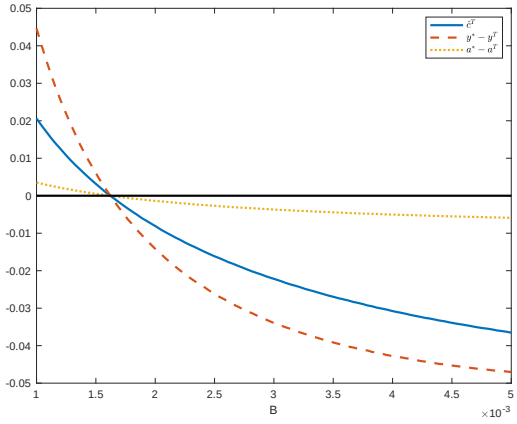
Role of Correlated Noise

- Uncorrelated noise ($\tau_\eta \to \infty$)
  - efficiency in trade implies efficiency in information acquisition
  - aggregate volume of trade $\tilde{x}$ invariant in y under efficient orders
  - higher $y \to$ lower dispersion
  - dispersion already optimal under efficient trading
- **Correlated noise** $\tau_\eta \in (0, +\infty)$
  - agents don't internalize effect of y on cov. of aggregate trade $\tilde{x}$ with shocks (θ, u, η)
  - cov. matters for non-fundamental volatility

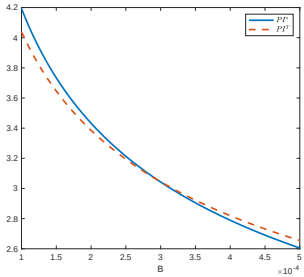
Historical Reduction in Cost of Information

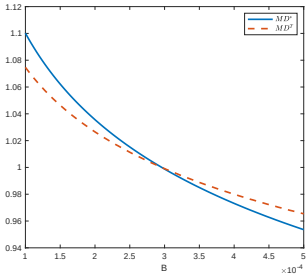
- Reduction in cost of information $\rightarrow$ higher y
- Pecuniary externality $\Xi(a^T)$ increasing in y
- Learning externality $\Delta(a^T)$ non-monotone in y
- Low cost of information:
  - excessive acquisition of information
  - inefficiently high sensitivity of trades to private information

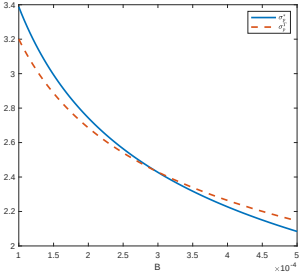
Historical Reduction in Cost of Information



Other Market Variables







- PI (price informativeness)
- MD (market depth): inverse sensitivity of price to noise shocks
- PV (price volatility): standard deviation of price

Optimal Policy Mix

Impossibility Result

Proposition

Generically, there exists no policy $T(x_i, p)$ measurable in

(a) price, p

(b) individual volume of trade, x_i

inducing efficiency in **both** information acquisition and trading

- Unique policy inducing efficient trading
  - creates wedge between private and social (marginal) value of information

Possibility Result 1

Proposition

If acquisition **verifiable**, efficiency in **both** acquisition and trading through tax policy

$$T(x_i, p, y_i) = \frac{\delta}{2} x_i^2 + (pt_p - t_0)\, x_i - A y_i$$

- (non-linear) tax $\frac{\delta}{2} x_i^2 + (pt_p - t_0)\, x_i \rightarrow$ efficient **trading**
- subsidy/tax Ay_i on info purchases $\rightarrow$ efficient **acquisition**
  - $A > 0$ (subsidy) when pecuniary externality $<$ learning externality
  - $A < 0$ (tax) when pecuniary externality $>$ learning externality

Possibility Result 2

Proposition

Suppose info acquisition not verifiable. Efficiency in **both** acquisition and trading through tax policy

$$T(x_i, p, \tilde{x}) = \frac{\delta^*}{2} x_i^2 + (t_{\tilde{x}}^* \tilde{x} - t_0^*)\, x_i + t_p^* p x_i$$

where marginal rate contingent on **aggregate volume of trade,** $\tilde{x}$

- Dependence of marginal rate on aggregate volume of trade
  - uncertainty about marginal tax rate $t_{\tilde{x}}^*$
  - permits planner to manipulate incentives for acquisition while retaining efficiency in trading

Ad-Valorem Taxes

Proposition

Suppose planner restricted to **ad-valorem taxes**

$$T(x_i, p) = t_p p x_i$$

Then, no matter whether info is exogenous or endogenous, optimal $t_p = 0$.

- Ad-valorem taxes have no effect on
  - acquisition of private information
  - sensitivity of eq. limit orders to private info
- They manipulate
  - sensitivity of eq. limit orders to price, c
  - ex-ante volume of trade, b
  - however, b and c are efficient under laissez-fare (given y and a^*)

Market Orders

- Suppose traders restricted to mkt orders:

$$X_i(s) = as_i + b$$

- No externalities
- Efficient trading and information acquisition
- However, welfare can be lower than under limit orders

Conclusions

Conclusions

- Historical decline in cost of information:
  - over-investment in information
  - over-sensitivity of financial trades to private information
- Efficiency in trading does not guarantee efficiency in info acquisition
- Efficiency in **both acquisition and trading**
  - taxes/subsidies on info purchases (when info acquisition verifiable)
  - conditioning tax rates on **aggregate volume of trade**

Conclusions

- Other market-design interventions may help
  - regulation of trade frequency
  - public info disclosures
  - orders conditional on aggregate volume of trade

THANK YOU!