Information Choice

in Macroeconomics and Finance

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"What information consumes is rather obvious: It consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."

Herbert Simon (1971)

Why Study Information Choice?

- The world economy is shifting from producing goods to producing knowledge.
- Within all firms, enormous resources are devoted decision-making: acquiring and processing information to arrive at a decision.
- What information do people choose to observe and process? How does this affect aggregate prices and economic activity?
- Every stochastic model employs expectations. What information sets are these expectations founded on?

Outline

- Preliminaries: Measuring information flows: inattentiveness (Reis 2006), independent signal draws (Wilson 1975), rational inattention (Sims 2003).
- 1 Theme: Strategic Motives in Information Choice
  - A strategic game with information choice. What do agents choose to learn?
  - A simple example: Investment with externalities
  - Application: a model of home bias
- Other themes of the book
- Applications and future research ideas

Measuring Information: Inattentiveness

- Inattentiveness: Pay a cost to update fully. In between updates, no information of any kind is processed.
- More information means more frequent updates.
- A fixed-cost technology.
- Represents: Looking up straightforward information (e.g. a checking account balance).

Measuring Information: Independent Signal Draws

- A constraint on additive precision - If there are n events to learn about and signals precisions are $\tau_1, \tau_2, \ldots, \tau_n$, then information cost is a function of $\sum_{i=1}^{n} \tau_i$.
- Why is this a limit on the number of draws? Bayes' rule for normal variables:
  Posterior precision = prior precision + sum of all signal precisions
  If each signal has precision ϵ, then any cost of total precision $\sum_{i=1}^{n} \tau_i$ can be expressed as a cost of v signals, where $v = \sum_{i=1}^{n} \tau_i / \epsilon$.

Measuring Information: Rational Inattention

- Information cost depends on the extent to which the information reduces the entropy. For normal variables, this is a bound on the determinant of posterior precision matrix. For independent assets, $|\Sigma^{-1} + \Sigma_\eta^{-1}| = \prod_{i=1}^n (\Sigma_{ii}^{-1} + \Sigma_{\eta ii}^{-1}) \leq K$.
- An approximation to the number of 0's and 1's needed to transmit this precise a signal in binary code.
  - An efficient coding algorithm bisects the event space repeatedly.
- This measure represents an iterative search process. Knowledge is cumulative.

Strategic Motives in Information Acquisition

- Beauty content game
  - Based on Hellwig and Veldkamp "Knowing What Others Know" (ReStud, 2009)
  - Used in many settings where strategic interactions play a central role, including games of price adjustment, bank runs and financial crises, political economy, production in business cycles.
  - A second-order Taylor expansion to many objectives.
  - State a general result
- Use a simple model of real investment to provide the intuition.

A Beauty Contest Game

- Continuum of agents. Each agent sets a_i to minimize

$$EL\left(a_i, a, s\right) = E\left[\left(1-r\right)\left(a_i - s\right)^2 + r\left(a_i - a\right)^2\right]$$

where $a = \int a_i di$. Exogenous state variable: $s \sim \mathcal{N}\left(y, \tau_s^{-1}\right)$.

- First-order condition: is $a_i = \left(1-r\right) E_i[s] + r E_i[a]$.

- The key parameter is r:

$$\begin{aligned} r &> 0: \text{ Strategic complements, optimal } a_i \text{ increasing in } a. \\ r &= 0: \text{ No interaction, optimal } a_i \text{ independent of } a. \\ r &< 0: \text{ Strategic substitutes, optimal } a_i \text{ decreasing in } a. \end{aligned}$$

Order of Events

1. Natures draws $s \sim \mathcal{N}\left(y, \tau_s^{-1}\right)$.
2. Each agent receives exogenous private signal $x_i \sim \mathcal{N}\left(s, \tau_x^{-1}\right)$.
3. Agents decide how much to pay $C(\tau_w, \tau_z)$ (increasing, convex, twice differentiable) to acquire additional information:
   - private signal $w_i \sim \mathcal{N}\left(s, \tau_w^{-1}\right)$
   - common signal $z \sim \mathcal{N}\left(s, \tau_z^{-1}\right)$.
     Agent chooses how far to read on a string of signals.
4. Agents choose a_i.

Symmetric equilibrium: τ_w^* or τ_z^*.

The Main Result

- Marginal value of private info: $B(\tau_w) = -\frac{\partial}{\partial \tau_w} EL(\tau_w, \tau_z; \tau_w^*, \tau_z^*)$
  Marginal value of public info: $B(\tau_z) = -\frac{\partial}{\partial \tau_z} EL(\tau_w, \tau_z; \tau_w^*, \tau_z^*)$.

- **Proposition:**

$$\begin{aligned} r &> 0 \iff \frac{\partial}{\partial \tau_w^*} B(\tau_w), \frac{\partial}{\partial \tau_z^*} B(\tau_z) > 0 \\ r &= 0 \iff \frac{\partial}{\partial \tau_w^*} B(\tau_w), \frac{\partial}{\partial \tau_z^*} B(\tau_z) = 0 \\ r &< 0 \iff \frac{\partial}{\partial \tau_w^*} B(\tau_w), \frac{\partial}{\partial \tau_z^*} B(\tau_z) < 0 \end{aligned}$$

- Complementarity ($r > 0$): High $\tau_w + \tau_z$ raises cov(a,s), creates more payoff uncertainty, raises information value.

- Substitutability ($r < 0$): High $\tau_w + \tau_z$ raises cov(a,s), creates less payoff uncertainty, lowers information value.

A simple model of firms' investment

- A continuum of firms i choose capital k_i to maximize

$$E\left[\left[(1-r)\,s + rK\right]k_i - \frac{1}{2}k_i^2\right]$$

$s \sim N(y, \sigma^2)$, $K = \int k_i\, di$, $r \in (-1, 1)$.

- A firm can pay C to learn s (without noise).
- Nash equilibrium: k^I, k^U and fraction informed.

Solving the investment model

- First-order condition:

$$k_i = (1-r)\,E_i(s) + rE_i(K)$$

- If all informed, $E_i(s) = s$,

$$K = \int k_i di = (1-r)s + rK \quad \Rightarrow \quad K = s$$

Aggregate investment covaries with s.

- If all uninformed, $E_i(s) = y$,

$$K = \int k_i di = (1-r)y + rK \quad \Rightarrow \quad K = y$$

Aggregate investment does not covary with s.

Investment model: Four cases

- Expected profit: $\frac{1}{2}\left[(1-r)\,E_i(s)+rE_i(K)\right]^2$.

Expected Profit	Others are Informed	Others are Uninformed
Become Informed	$\frac{1}{2}y^2+\frac{1}{2}\sigma^2$	$\frac{1}{2}y^2+\frac{1}{2}\left(1-r\right)^2\sigma^2$
Remain Uninformed	$\frac{1}{2}y^2$	$\frac{1}{2}y^2$

- Complementarity: If $r>0$ and others learn, then $rK=rs$, which covaries positively with $(1-r)s$. Positive covariance $\rightarrow$ more risk, more valuable information.
- Substitutability: If $r<0$ and others learn, then $rK=rs$, which covaries negatively with $(1-r)s$. Negative covariance $\rightarrow$ less risk, less valuable information.

Intuition

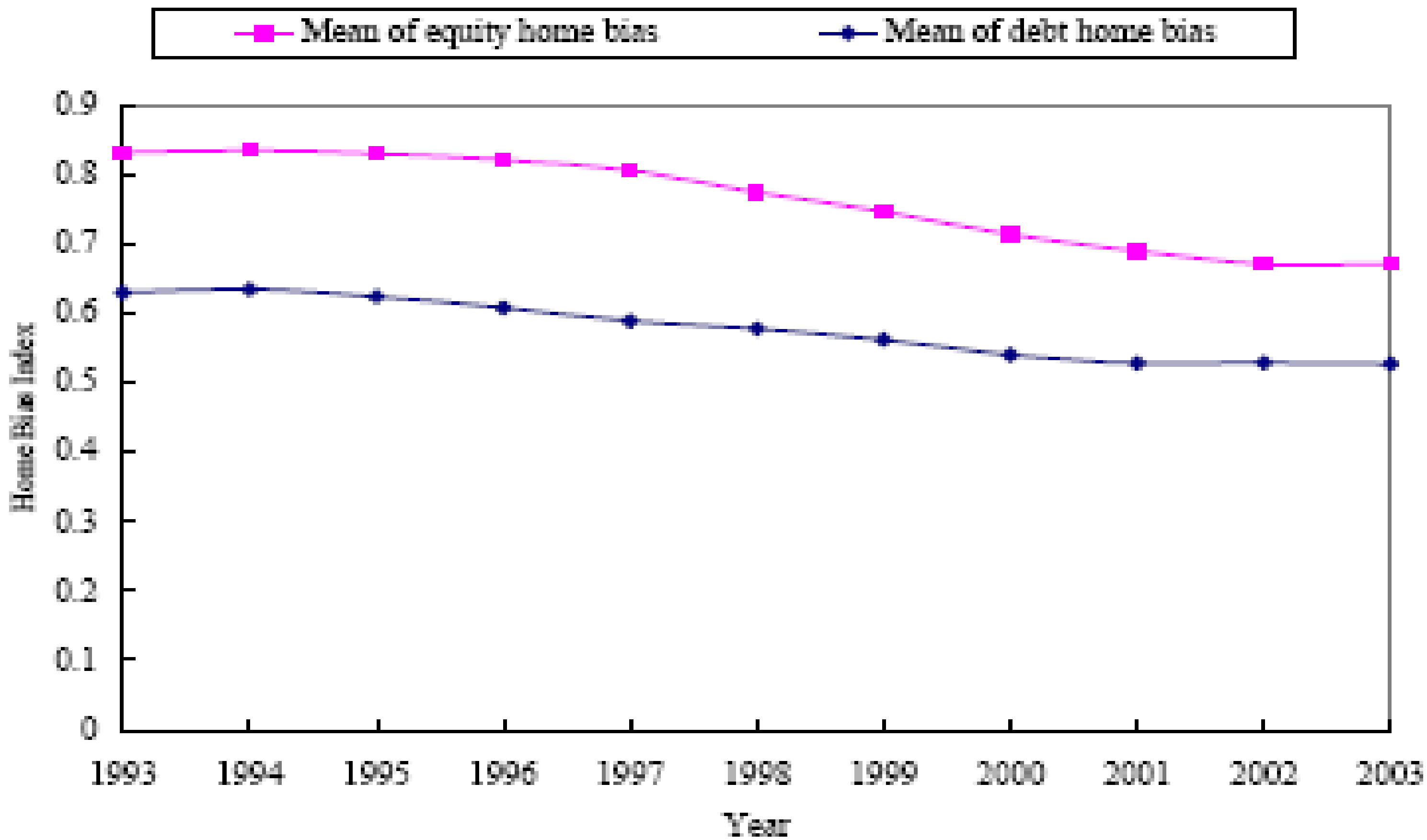
- When others learn, their actions covary more with the unknown state.
- If actions are substitutes, this hedges risk. You want to align with the state, but not with others' actions. Less risk makes information less valuable.
  You learn less when others learn more (substitutability).
- If actions are complements, others' learning amplifies risk. If you get the state wrong, your action will also be misaligned with others'. Extra risk makes learning about the state more valuable.
  You learn more when others learn more (complementarity).

Applying the General Result: Home Bias

- An application illustrates why this result might be important.
- Asset markets exhibit substitutability: I don't want to buy assets others are buying because those assets are expensive.
- Substitutability in information: I want to make my information set as different as possible from others' information so that I don't end up buying the assets they want to buy.
- To make your information set most different, take what you initially know more about it and acquire more information about that → home bias.
- A model based on Van Nieuwerburgh and Veldkamp, "Information Immobility and the Home Bias Puzzle" (J.Finance, June 2009).

The Home Bias Puzzle

- One of the major puzzles in international finance:

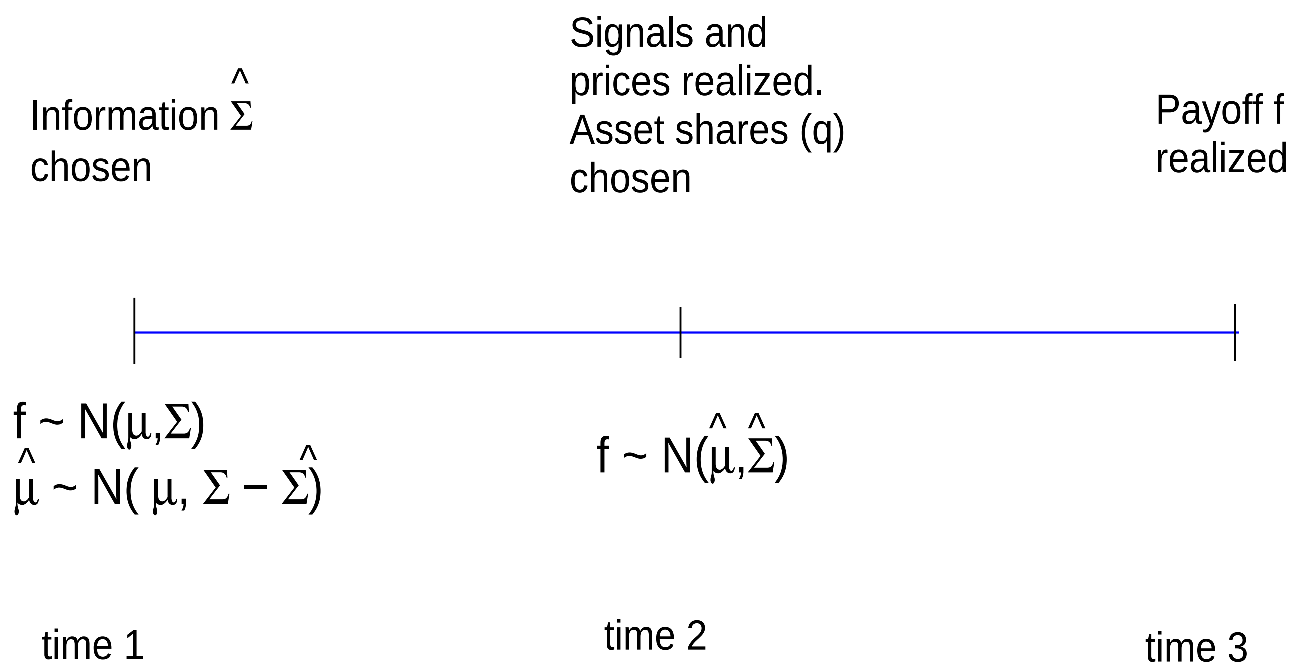


Notes. Mean of equity home bias and mean of debt home bias are the cross-sectional mean for 22 OECD countries.

Home Bias: Model Setup

- Continuum of atomless investors in each country.
- **Initial home advantage**: prior variance is lower for home assets.
- Maximize expected utility: $U_i = E_i[-e^{-\rho_i W_i}]$ where $W_i = r(W_0 - q'p) + q'f$.
- Random asset endowments $x \sim N(\bar{x}, \sigma_x^2 I) \Rightarrow$ noisy price.
- Choose signal precision Σ_η^{-1} s.t.
  - Capacity constraint: $|\Sigma^{-1} + \Sigma_\eta^{-1}| \leq K|\Sigma^{-1}|$,
  - No-forgetting constraint: $\Sigma - \widehat{\Sigma}$ is p.s.d.
  - Simplifying assumption: independent assets (Σ, $\widehat{\Sigma}$ diagonal).
- After observing signal and prices p, choose asset portfolio q.

Home Bias: Timing of Events



Solution method: Backwards Induction

1. Solve portfolio problem for arbitrary posterior beliefs $\widehat{\Sigma}_i$, $\hat{\mu}_i$.

$$q_i = \frac{1}{\rho}\widehat{\Sigma}_i^{-1}(\hat{\mu}_i - pr)$$

2. Solve for price p by imposing market clearing: $\int q_i di = x$.
3. Back out what is learned from prices: $(rp - A) \sim N(f, \Sigma_p)$. Price noise reflects average uncertainty: $\Sigma_p = \rho^2 \widehat{\Sigma}_a \widehat{\Sigma}_a$.
4. Substitute q, p and Σ_p into the period-1 objective and compute expected utility.
5. Determine optimal information choice (Σ_η^{-1}) for an individual, conditional on aggregate choice.
6. Describe aggregate capacity allocation and home bias.

Home Bias: What To Learn About?

Proposition: *Investor i uses all capacity to learn about the risk j with the highest* ***learning index****:* $\frac{\Sigma_{jj}^{-1} K + (\Sigma_p^{-1})_{jj}}{\Sigma_{jj}^{-1} + (\Sigma_p^{-1})_{jj}}$

Since $K > 1$, learn about an asset that

- has noisy prices: low $(\Sigma_p^{-1})_{jj}$.
  Strategic substitutability
- you know more about initially: high Σ_{jj}^{-1}
  Learning amplifies information asymmetry.

Just like **comparative advantage** in trade.

Home Bias: Optimal Portfolio

- Recall $q_i = \frac{1}{\rho}\widehat{\Sigma}_i^{-1}(\hat{\mu}_i - pr)$. Since $(\hat{\mu}_i - pr) > 0$ on average, more information (high $\widehat{\Sigma}_i^{-1}$) means i holds more of the asset.
- Learn more about home assets $\rightarrow$ invest in more home assets (home bias).
- Why buy more home assets?
  - Investors who are more informed that average investor are compensated for more risk than they bear.

Strategic Motives in Different Contexts

- Portfolio investment : Substitutability
  - Under-diversification
  - Segmented markets - Might investors be rationally specializing in information acquisition, which leads them to actively trade in only a small set of assets?
- Portfolio management: Substitutability
- Financial panics: Complementarity
- Price-setting: Complementarity
- Goods production in competitive markets: Substitutability.

Other Topics Covered in the Book

- Global games (Morris and Shin 1998)
- The social value of public information (Morris and Shin 2002)
- Information inertia and price-setting (Reis (2006) Maćkowiak and Wiederholt (2009))
- News-driven business cycles (Beaudry and Portier (2004), Jaimovich and Rebelo (2009))
- Evaluating information-based theories empirically

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(Slides and book draft available now on my website.)