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 $\epsilon$, 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

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

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

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

- The key parameter is $r$:

  $r > 0$ : Strategic complements, optimal $a_i$ increasing in $a$.
  
  $r = 0$ : No interaction, optimal $a_i$ independent of $a$.

  $r < 0$ : Strategic substitutes, optimal $a_i$ decreasing in $a$. 
1. Natures draws $s \sim \mathcal{N}(y, \tau_s^{-1})$.

2. Each agent receives exogenous private signal $x_i \sim \mathcal{N}(s, \tau_x^{-1})$.

3. Agents decide how much to pay $C(\tau_w, \tau_z)$ (increasing, convex, twice differentiable) to acquire additional information:
   - private signal $w_i \sim \mathcal{N}(s, \tau_w^{-1})$
   - common signal $z \sim \mathcal{N}(s, \tau_z^{-1})$.

   Agent chooses how far to read on a string of signals.

4. Agents choose $a_i$.

**Symmetric equilibrium**: $\tau_w^*$ or $\tau_z^*$. 

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**Order of Events**

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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:

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

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

• Substitutability \((r < 0)\): High \(\tau_w + \tau_z\) raises \(\text{cov}(a,s)\), creates less payoff uncertainty, lowers information value.
A simple model of firms’ investment

• A continuum of firms $i$ choose capital $k_i$ to maximize

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

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

• 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, \( E_i(s) = s \),

\[ K = \int k_i di = (1 - r)s + rK \Rightarrow K = s \]

Aggregate investment covaries with \( s \).

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

\[ K = \int k_i di = (1 - r)y + rK \Rightarrow K = y \]

Aggregate investment does not covary with \( s \).
Investment model: Four cases

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

<table>
<thead>
<tr>
<th>Expected Profit</th>
<th>Others are Informed</th>
<th>Others are Uninformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Become Informed</td>
<td>( \frac{1}{2} y^2 + \frac{1}{2} \sigma^2 )</td>
<td>( \frac{1}{2} y^2 + \frac{1}{2} (1 - r)^2 \sigma^2 )</td>
</tr>
<tr>
<td>Remain Uninformed</td>
<td>( \frac{1}{2} y^2 )</td>
<td>( \frac{1}{2} y^2 )</td>
</tr>
</tbody>
</table>

- 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.
• 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 \( \Sigma^{-1}_\eta \) s.t.
  - Capacity constraint: \( |\Sigma^{-1} + \Sigma^{-1}_\eta| \leq K|\Sigma^{-1}|, \)
  - No-forgetting constraint: \( \Sigma - \hat{\Sigma} \) is p.s.d.
  - Simplifying assumption: independent assets (\( \Sigma, \hat{\Sigma} \) diagonal).

- After observing signal and prices \( p, \) choose asset portfolio \( q. \)
**Home Bias: Timing of Events**

Information \( \Sigma \) chosen

Signals and prices realized.
Asset shares \( (q) \) chosen

Payoff \( f \) realized

\[ f \sim N(\mu, \Sigma) \]

\[ \hat{\mu} \sim N(\mu, \Sigma - \Sigma) \]

\[ f \sim N(\hat{\mu}, \Sigma) \]

\[ \text{time 1} \quad \text{time 2} \quad \text{time 3} \]
Solution method: Backwards Induction

1. Solve portfolio problem for arbitrary posterior beliefs $\hat{\Sigma}_i, \hat{\mu}_i$.
   \[ q_i = \frac{1}{\rho} \hat{\Sigma}_i^{-1} (\hat{\mu}_i - pr) \]

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: $\Sigma_p = \rho^2 \hat{\Sigma}_a \hat{\Sigma}_a$.

4. Substitute $q$, $p$ and $\Sigma_p$ into the period-1 objective and compute expected utility.

5. Determine optimal information choice ($\Sigma_{\eta}^{-1}$) 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 $\Sigma_{jj}^{-1}$
  
  *Learning amplifies information asymmetry.*

Just like *comparative advantage* in trade.
Home Bias: Optimal Portfolio

- Recall $q_i = \frac{1}{\rho} \Sigma_i^{-1} (\hat{\mu}_i - pr)$. Since $(\hat{\mu}_i - pr) > 0$ on average, more information (high $\Sigma_i^{-1}$) 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)
- Evaluating information-based theories empirically
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( Slides and book draft available now on my website.)