Identifying Price Informativeness

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How much information is revealed by asset prices?

- Price informativeness: measures the precision of information in price
- Disconnect between theoretical work and empirical measures of informativeness
How much information is revealed by asset prices?

- Price informativeness: measures the precision of information in price
- Disconnect between theoretical work and empirical measures of informativeness

This paper

- Methodology to identify price informativeness from linear regressions of prices on asset payoffs
- Recover \textit{exact} measures of stock specific price informativeness
  - Absolute and relative price informativeness
Main Results

1. Identifying price informativeness
   ▶ Identify exact measures of price informativeness (precision of info in price)
   ▶ Illustration of identification results
     ▶ Regression of prices on current and future payoffs
       \[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \varepsilon_t \]
     ▶ Price informativeness = signal to noise ratio
       \[ \tau_p = \frac{\beta_2^2}{\text{Var} [\varepsilon_t]} \]
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   - Price informativeness = signal to noise ratio
     \[ \tau^*_p = \frac{\beta^2_2}{\text{Var} [\epsilon_t]} \]

2. Empirical implementation
   - Prices are noisy: median updating weight is 0.02 and mean is 0.05
     - Dispersed and right-skewed distribution of informativeness measures
   - Informativeness increases in market cap, in turnover, and over time.
   - Informativeness is higher at lower frequencies
Why Price Informativeness?

“The economic problem of society is (...) rather a problem of how to secure the best use of resources known to any of the members of society, for ends whose relative importance only these individuals know. Or, to put it briefly, it is a problem of the utilization of knowledge which is not given to anyone in its totality.”

Hayek, 1945
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Hayek, 1945

- Which stocks/industries to learn about?
- Identify good investment opportunities more precisely
Outline

1. **Identifying price informativeness**
   - Framework
   - Identification
   - Extensions

2. **Empirical implementation**
   - Estimates of price informativeness
   - Distribution of price informativeness across stock characteristics
One asset traded at price $p_t$ with an unobserved payoff

$$\theta_{t+1} = \mu + \rho \theta_t + \eta_t,$$

where $|\rho| < 1$ and $\eta_t$ are i.i.d., mean zero with variance $\tau^{-1}_\eta$. Investors have two privately observed trading motives:

1. Private signal about the innovation to the payoff $s_i(t)$ (information).
2. Private idiosyncratic trading motive, $n_i(t)$ (noise).
Framework

- One asset traded at price $p_t$ with an unobserved payoff

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  2. Private idiosyncratic trading motive, $n^i_t$ (noise)
Assumptions

1. **Additive noise**
   - Signals about innovation to payoff
     \[ s^i_t = \eta^i_t + \varepsilon^i_{st} \]
   - Idiosyncratic trading motives
     \[ n^i_t = \underbrace{n_t}_{\text{aggregate}} + \underbrace{\varepsilon^i_{nt}}_{\text{idiosyncratic}} \]
     where \( n_t \) is unobserved and \( \text{Var}[n_t] = \tau_n^{-1} \)

2. **Linear asset demands**
\[
\Delta q^i_t = \alpha^i_\theta \theta_t + \alpha^i_s s^i_t + \alpha^i_n n^i_t - \alpha^i_p p_t + \psi^i
\]
Assumptions

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- **General structure**
  - Agnostic about trading motives, distributional assumptions, learning technology, investor heterogeneity
  - First order approximation to more general demand functions
Price Informativeness

Linear equilibrium price

\[ p_t = \pi_\theta \theta_t + \{ \pi_s \eta_t + \pi_n n_t \} + \text{risk premium} \]
Price Informativeness

Linear equilibrium price

\[ p_t = \pi_\theta \theta_t + \pi_s \eta_t + \pi_n n_t + \text{risk premium} \]

- **Absolute Price Informativeness:**

\[ \tau_{p} \equiv \text{precision of information in price} \]
Price Informativeness

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▶ Absolute Price Informativeness:

\[ \tau_p \equiv \text{precision of information in price} = \left( \frac{\pi_s}{\pi_n} \right)^2 \tau_n \]
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**Absolute Price Informativeness:**

\[ \tau_p \equiv \text{precision of information in price} = \left( \frac{\pi_s}{\pi_n} \right)^2 \tau_n \]

**Relative Price informativeness:**

\[ \tau_p^R = \frac{\text{precision of info in price}}{\text{precision of innovation}} = \frac{\tau_p}{\tau_\eta} \]
Price Informativeness

Linear equilibrium price

\[ p_t = \pi_\theta \theta_t + \pi_s \eta_t + \pi_n n_t + \text{risk premium} \]

- **Absolute Price Informativeness:**

\[ \hat{\tau}_p \equiv \text{precision of information in price} = \left( \frac{\pi_s}{\pi_n} \right)^2 \tau_n \]

- **Relative Price informativeness:**

\[ \hat{\tau}_p^R = \frac{\text{precision of info in price}}{\text{precision of innovation}} = \frac{\hat{\tau}_p}{\tau_\eta} \]

- **Updating weight (Kalman Gain):** 

\[ K = \frac{\hat{\tau}_p^R}{1 + \hat{\tau}_p^R} \text{, where} \]

\[ \text{Posterior Belief} = (1 - K) \times \text{Prior Belief} + K \times \text{Signal in Price} \]
Identifying Absolute Price Informativeness

Identification Result 1

Absolute price informativeness can be recovered by regressing prices on payoffs

\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \varepsilon_t, \]  

(R1)

as

\[ \tau^p = \frac{\beta_2^2}{\text{Var}[\varepsilon_t]} . \]
Identifying Absolute Price Informativeness

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as

\[ \tau_p = \frac{\beta_2^2}{\text{Var}[\varepsilon_t]}. \]

▶ Equilibrium price

\[ p_t = \text{risk premium}_{\beta_0} + (\pi_\theta - \pi_s \rho)\theta_t + \pi_s \theta_{t+1} + \pi_n n_t = \beta_1 + \beta_2 + \varepsilon_t \]
Identifying Absolute Price Informativeness

Identification Result 1

Absolute price informativeness can be recovered by regressing prices on payoffs

\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \epsilon_t, \]  

(R1)

as

\[ \hat{\tau}_p = \frac{\beta_2^2}{\text{Var}[\epsilon_t]} . \]

▶ Equilibrium price

\[ p_t = \left[ \begin{array}{c} \text{risk premium} \\ = \beta_0 \\ \end{array} \right] + \left[ \begin{array}{c} \pi_\theta - \pi_{sp} \rho \theta_t \\ = \beta_1 \theta_t \\ \end{array} \right] + \left[ \begin{array}{c} \pi_s \theta_{t+1} \\ = \beta_2 \theta_{t+1} \\ \end{array} \right] + \left[ \begin{array}{c} \pi_n n_t \\ = \epsilon_t \\ \end{array} \right] \]

▶ Price informativeness \( \hat{\tau}_p = \left( \frac{\pi_s}{\pi_n} \right)^2 \tau_n \)
Identifying Absolute Price Informativeness

Identification Result 1

Absolute price informativeness can be recovered by regressing prices on payoffs

\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \epsilon_t, \quad \text{(R1)} \]

as

\[ \hat{\tau}_p = \frac{\beta^2_2}{\operatorname{Var} \{\epsilon_t\}}. \]

▶ Equilibrium price

\[ p_t = \underbrace{\text{risk premium}}_{\beta_0} + \underbrace{\left(\pi_\theta - \pi_s \rho\right) \theta_t}_{\beta_1} + \underbrace{\pi_s \theta_{t+1}}_{\beta_2} + \underbrace{\pi_n n_t}_{\epsilon_t} \]

▶ Price informativeness

\[ \tau_p = \left(\frac{\pi_s}{\pi_n}\right)^2 \tau_n = \frac{\beta^2_2}{\operatorname{Var} \{\epsilon_t\}} \]
Identifying Relative Price Informativeness

Identification Result 2

Relative price informativeness can be recovered from regressions of prices on payoffs

\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \varepsilon_t \Rightarrow R^2_{|\theta_{t+1},\theta_t} \quad (R1) \]

\[ p_t = \zeta_0 + \zeta_1 \theta_t + \varepsilon_t \Rightarrow R^2_{|\theta_t} \quad (R2) \]

using the R-squareds as follows

\[ \tau^R_p = \frac{R^2_{|\theta_{t+1},\theta_t} - R^2_{|\theta_t}}{1 - R^2_{|\theta_{t+1},\theta_t}} \]
Identifying Relative Price Informativeness

Identification Result 2

Relative price informativeness can be recovered from regressions of prices on payoffs

\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \varepsilon_t \Rightarrow R^2_{|\theta_{t+1}, \theta_t} \]  \hspace{1cm} (R1)

\[ p_t = \zeta_0 + \zeta_1 \theta_t + \varepsilon_t \Rightarrow R^2_{|\theta_t} \]  \hspace{1cm} (R2)

using the R-squareds as follows

\[ \tau^R_p = \frac{R^2_{|\theta_{t+1}, \theta_t} - R^2_{|\theta_t}}{1 - R^2_{|\theta_{t+1}, \theta_t}} \]
Why this definition of informativeness?

1. Blackwell’s (1951) notion of informativeness to rank signals (experiments)
   ▶ More informative signals are associated with lower expected losses for decision maker
   ▶ Quadratic loss function + unbiased signals $\Rightarrow$ signal precision $\hat{\tau}_p$ induces an order
Why this definition of informativeness?

1. Blackwell’s (1951) notion of informativeness to rank signals (experiments)
   ▶ More informative signals are associated with lower expected losses for decision maker
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2. Gaussian signal structure + Bayesian updating
   ▶ $\tau_p$ is the only relevant object to form a posterior, given the signal
Predictability is not Informativeness

- Predictability measures confound two objects
  - price informativeness: how well prices reveal asset payoffs
  - payoff volatility: how easy it is to forecast asset payoffs
Predictability is not Informativeness

- Predictability measures confound two objects
  - price informativeness: how well prices reveal asset payoffs
  - payoff volatility: how easy it is to forecast asset payoffs

- Without a structural interpretation cannot interpret magnitudes
  - Need assumptions on distributions and updating rules
Extensions

1. Non-stationary payoffs
   ▶ Extend results running regressions in differences

2. Learnable and unlearnable components of asset payoff
   ▶ All identification results are valid, interpretation of noise differs

3. Public signals
   ▶ All identification results are valid, implementation may differ

4. Payoff correlated with noise

5. Multiple risky assets with correlated payoffs
Non-stationary payoffs

- Non-stationary payoffs
  \[ \Delta \theta_t = \mu_\theta + \eta_t \]

- Cannot estimate Regression R1 using OLS
Non-stationary payoffs

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  \[ \Delta \theta_t = \mu_{\theta} + \eta_t \]

- Cannot estimate Regression R1 using OLS

- Regressions in differences
  \[
  \Delta p_t = \beta_0 + \beta_1 \Delta \theta_t + \beta_2 \Delta \theta_{t+1} + \hat{\epsilon}_t \\
  \Delta p_t = \zeta_0 + \zeta_1 \Delta \theta_t + \hat{\epsilon}_t^\zeta
  \]
Non-stationary payoffs

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  \[ \Delta \theta_t = \mu_{\theta} + \eta_t \]

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- Regressions in differences
  \[
  \Delta p_t = \beta_0 + \beta_1 \Delta \theta_t + \beta_2 \Delta \theta_t + \hat{\epsilon}_t \Rightarrow R^2_{\Delta \theta_{t+1}, \Delta \theta_t} \\
  \Delta p_t = \zeta_0 + \zeta_1 \Delta \theta_t + \hat{\zeta}_t \Rightarrow R^2_{\Delta \theta_t}
  \]

- Price informativeness
  \[
  \tau_\hat{p} = 2 \frac{\beta_2^2}{\text{Var} [\hat{\epsilon}_t]} \quad \text{and} \quad \tau^R_\hat{p} = 2 \frac{R^2_{\Delta \theta_{t+1}, \Delta \theta_t} - R^2_{\Delta \theta_{t+1}, \Delta \theta_{t-1}}}{1 - R^2_{\Delta \theta_{t+1}, \Delta \theta_t}}
  \]
Learnable and unlearnable payoff

- Two components of asset payoff: learnable and unlearnable
  \[ \eta_t = \eta^L_t + \eta^U_t \]

- Private signal of learnable component
  \[ s^i_t = \eta^L_t + \varepsilon^i_{st} \]
Learnable and unlearnable payoff

▶ Two components of asset payoff: learnable and unlearnable

\[ \eta_t = \eta_t^L + \eta_t^U \]

▶ Private signal of learnable component

\[ s_t^i = \eta_t^L + \epsilon_{st}^i = \eta_t - \eta_t^U + \epsilon_{st}^i = \eta_t + \epsilon_{st}^i' \]
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- Equilibrium price

\[ p_t = \beta_0 + \beta_1 \vartheta_t + \beta_2 \vartheta_{t+1} + \frac{\alpha_n}{\alpha_p} n_t - \frac{\alpha_s}{\alpha_p} \eta_{t+1}^U + \varepsilon_t \]
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\[ p_t = \beta_0 + \beta_1 \theta_t + \beta_2 \theta_{t+1} + \frac{\overline{\alpha_n}}{\overline{\alpha_p}} n_t - \frac{\overline{\alpha_s}}{\overline{\alpha_p}} \eta_{t+1}^U + \left[ \epsilon_t \right] \]

- Identification results remain valid, interpretation of noise differs
Public signals

- Investors receive a public signal of innovation to payoff

\[ \pi_t = \eta_t + \varepsilon_{\pi t} \]

- Linear asset demands

\[ \Delta q^i_t = \alpha^i_\theta \theta_t + \alpha^i_s s^i_t + \alpha^i_\pi \pi_t + \alpha^i_n n^i_t - \alpha^i_p p_t + \psi^i, \]
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- Observing the public signal

  - Price

\[ p_t = \chi_0 + \chi_1 \theta_t + \chi_2 \theta_{t+1} + \chi_3 \pi_t + \overline{\alpha_n \overline{\alpha_p}} n_t \]

\[ = \tilde{\varepsilon}_t \]
Public signals

- Investors receive a public signal of innovation to payoff

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- Linear asset demands

\[ \Delta q^i_t = \alpha^i_\theta \theta^i_t + \alpha^i_s s^i_t + \alpha^i_\pi \pi^i_t + \alpha^i_n n^i_t - \alpha^i_p p_t + \psi^i, \]

- Observing the public signal
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\[ p_t = \chi_0 + \chi_1 \theta_t + \chi_2 \theta_{t+1} + \chi_3 \pi_t + \underbrace{\frac{\alpha_n}{\alpha_p} n_t}_{= \tilde{\varepsilon}_t} \]

- Implementation changes, same identification
Empirical Implementation

- Implement regressions R1 and R2 in our identifications results at the stock level
  - CRSP/Compustat, 1963-2017, quarterly data
  - Total market value, $M_t^j$
  - Quarterly earnings as a measure of the payoff, $E_t^j$
Empirical Implementation

▶ Main specification (stationary earnings)

\[ M_t^j = \beta_0^j + \beta_1^j E_{j,t} + \beta_2^j E_{j,t+1} + \varepsilon_t^j \Rightarrow R_{|\theta_{t+1},\theta_t}^{2j} \]
\[ M_t^j = \zeta_0^j + \zeta_1^j E_{j,t} + \hat{\varepsilon}_t^j \Rightarrow R_{|\theta_t}^{2j} \]

▶ Measures of price informativeness

\[ \tau_{\hat{p}}^j = \left( \frac{\beta_2^j}{\text{Var}[\varepsilon_t^j]} \right)^2, \quad \tau_{R_{\hat{p}}}^j = \frac{R_{|\theta_{t+1},\theta_t}^{2j} - R_{|\theta_t}^{2j}}{1 - R_{|\theta_{t+1},\theta_t}^{2j}} \text{ and } K^j = \frac{\tau_{\hat{p}}^{R_{\hat{p}}}}{1 + \tau_{R_{\hat{p}}}^{R_{\hat{p}}}} \]

▶ We test for non-stationarity of earnings

▶ Use adequate methodology given test

▶ Implicit assumption: structural stability of parameters
## Empirical Results

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Pctl(25)</th>
<th>Median</th>
<th>Pctl(75)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Informativeness</td>
<td>0.03</td>
<td>0.17</td>
<td>0.0000</td>
<td>0.001</td>
<td>0.01</td>
</tr>
<tr>
<td>Relative Informativeness</td>
<td>0.08</td>
<td>0.20</td>
<td>0.01</td>
<td>0.02</td>
<td>0.08</td>
</tr>
<tr>
<td>Kalman Gain</td>
<td>0.06</td>
<td>0.09</td>
<td>0.01</td>
<td>0.02</td>
<td>0.08</td>
</tr>
</tbody>
</table>
Price Informativeness

![Price Informativeness Graph](image)

- X-axis: Kalman gain
- Y-axis: Number of securities

The graph shows the distribution of securities across different levels of Kalman gain.
Price Informativeness by Exchange

Exchange: NYSE, AMEX, NASDAQ

Kalman Gain

Box plots showing the distribution of Kalman Gain across different exchanges.
Price Informativeness by Market Cap

![Graph showing the relationship between Kalman Gain and Market Capitalization (log)].

- **Market Capitalization (log)**: The x-axis represents the logarithm of market capitalization, ranging from approximately 20.08554 to 162754.79142.
- **Kalman Gain**: The y-axis represents the Kalman Gain, ranging from 0.0 to 0.4.

The scatter plot shows a positive correlation between Kalman Gain and Market Capitalization (log), with a trend line indicating the relationship.
Price Informativeness by Market Cap

![Graph showing the relationship between Kalman Gain and Market Capitalization (log).]
Price Informativeness by Turnover

![Graph showing the relationship between Kalman Gain and Turnover]

- **X-axis:** Turnover
- **Y-axis:** Kalman Gain

The graph illustrates the scatter plot of Kalman Gain against Turnover, with a trend line indicating the relationship between the two variables.
Price Informativeness by Turnover

![Graph showing the relationship between Kalman Gain and Turnover with data points and a trend line.]

- **Price Informativeness by Turnover**
- **Kalman Gain**
- **Turnover**

Data points are scattered across the graph, with a trend line indicating a positive correlation between Kalman Gain and Turnover.
Price Informativeness by Industry

![Price Informativeness by Industry](image-url)

- Agric./Mining/Construction
- Manufacturing
- Transportation
- Wholesale/Retail trade
- Finance/Insurance
- Services

Kalman Gain
Price Informativeness over time
Price Informativeness Annual Frequency

[Graph showing the distribution of Kalman gains with the y-axis labeled 'Number of securities' and the x-axis labeled 'Kalman gain'.]
Conclusion

- Methodology to recover exact measures of stock-specific price informativeness
  - General framework (rich heterogeneity, minimal distributional assumptions)
  - Stationary and non-stationary payoffs
  - Straight forward implementation

- Prices are not too informative
- Substantial dispersion in price informativeness
- Informativeness increases in market cap and turnover
- Informativeness increased over time for most stocks
- Informativeness is higher at lower frequencies
Conclusion

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