Market Efficiency with Micro and Macro Information

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Samuelson's Dictum (Jung and Shiller 2006)

Modern markets show considerable micro efficiency (for the reason that the minority who spot aberrations from micro efficiency can make money from those occurrences and, in doing so, they tend to wipe out any persistent inefficiencies). In no contradiction to the previous sentence, I had hypothesized considerable macro inefficiency, in the sense of long waves in the time series of aggregate indexes of security prices below and above various definitions of fundamental values.

(From a letter from Paul Samuelson to John Campbell and Robert Shiller.)

Motivating the micro/macro difference

- In earlier work, we measure the response of implied and realized volatility to unusual negative news
- Impulse response functions indicate that infation gets into prices more quickly for individual stocks than for the S&P 500

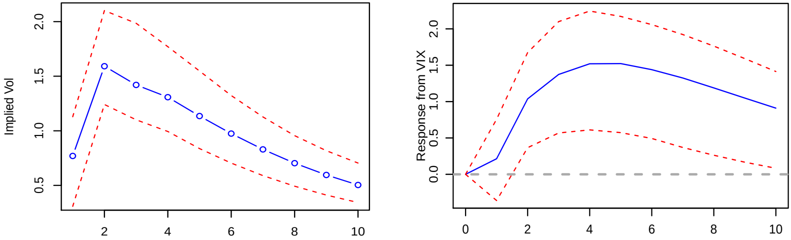

Figure: Response of individual stock volatilities to company-specific news (left) and response of VIX to aggregate news (right)

Overview

- We build a simple single-period model that allows investors to either:
    1. Remain uninformed
    2. Specialize in micro information
    3. Specialize in macro information
- Becoming informed carries a cost
- So does making inferences from prices of individual stocks about which an agent is not informed
- We analyze agents' optimal choices
    - and implications for micro and macro price efficiency (how much information is revealed through prices)
- Model is solvable in closed form, building on
    - Grossman and Stiglitz (1980), Admati and Pfleiderer (1987)
- *Overarching question:* Are markets prone towards micro efficiency and macro inefficiency?

The securities

- There are N stocks, with the i^{th} paying a dividend

$$u_i = \beta_i M + S_i, \quad i = 1, \ldots, N,$$

where

$$M = m + \epsilon_M \quad \text{and} \quad S_i = s_i + \epsilon_i$$

with

$$f_m = \frac{\sigma_m^2}{\sigma_M^2} \quad \text{and} \quad f_S = \frac{\sigma_s^2}{\sigma_S^2}$$

  - m and s_i are the knowable portion of the macro and micro dividends
  - f's determine the quality of attainable knowledge about the world
  - security prices are given by P_i and average β is 1
- There is an index fund F (price P_F) one share of which holds $1/N$ shares of each security

$$u_F = M + \frac{1}{N} \sum_{i=1}^{N} S_i$$

The investors

- Continuum (of unit measure) of investors
- $N + 1$ securities
- Agents maximize expected utility over time 2 wealth

$$\mathbb{E}[-\exp(-\gamma \tilde{W}_2)|\mathcal{I}]$$

  subject to their information sets
- All uncertainty is normally distributed
- Timing:
  0. Investors choose information sets
  1. Information is revealed, supply shocks occur, and trading takes place
  2. Dividends are paid

Information

- Three types of agents: uninformed U, macro M and micro informed S, with proportions
$$\lambda_U + \lambda_M + \lambda_S = 1$$
- Agents can choose to become informed at a cost of c
  - Informed agents choose to specialize in either *macro* or *micro* information
  - $1/N$ of micro informed are randomly allocated to learn about each stock i
- Inference from prices:
  - The macro uninformed (i.e. S and U) make proper inferences from P_F
  - We *restrict* agents uninformed about stock i from making inferences about s_i from P_i (and show this is justified by a small cost to making inferences)
    $\rightarrow$ **This is the key asymmetry in the model**

Supply shocks and market clearing

Supply shocks for individual stocks:

- Common component X_F — aggregate supply shock
- Idiosyncratic component X_i — noise trading in stock i

Market clearing

- Let q_F be the aggregate holdings of the index fund
- Market clearing requires that for each stock i:

$$\text{Direct demand for } i + q_F/N = \text{Supply of i}$$

- *The i uninformed have no direct demand*

market clearing, part i

Model timing

Time 0
Information equilibrium
Agents choose information sets subject to $\lambda_U + \lambda_M + \lambda_S = 1$

Time 1/2
Attention equilibrium
Informed agents specialize in either micro or macro subject to $\lambda_M + \lambda_S = 1 - \lambda_U$

Time 1
1) Macro and micro informed observe signals
2) Supply shocks arrive
3) Trading takes place in N securities

Time 2
Cash flows are realized

Agents' demands, given prices P_F and P_i

Agents set demands by maximizing

$$\mathbb{E}[-\exp(-\gamma \tilde{W}_2)|\mathcal{I}], \quad \tilde{W}_2 = q_F(u_F - RP_F) + q_i(u_i - RP_i)$$

with $q_i \neq 0$ only for i-informed investors

Proposition

Demands for the index fund are given by

$$q_F^{U/M} = \frac{\mathbb{E}[M|\mathcal{I}] - RP_F}{\gamma \mathrm{var}(M|\mathcal{I})}$$

The i-informed demands are given by

$$q_i^i = \frac{R}{\gamma(1-f_S)\sigma_S^2}(\beta_i P_F + s_i/R - P_i)$$

$$q_F^i = q_F^U - \beta_i q_i^i$$

Equilibrium

- We impose $\sum_{i=1}^{N} s_i = \sum_{i=1}^{N} \epsilon_i = \sum_{i=1}^{N} X_i = 0$ (exchangeable)

Proposition

(i) *Prices are given by*

$$P_F = a_F + b_F(m - \bar{m}) + c_F(X_F - \bar{X}_F)$$
$$P_i = \beta_i P_F + b_S s_i + c_S X_i$$

(ii) *Agents' demands are linear in prices*

(iii) *Quantities demanded satisfy*

$$(\lambda_U + \lambda_S) q_F^U + \lambda_M q_F^M = X_F$$
$$\lambda_S q_i^i = X_i$$

Price efficiency

- Macro price efficiency is the proportion of variability in P_F that comes from m (as opposed to X_F)
- We show that this is

$$\rho_F^2 = \frac{f_M}{f_M + \gamma^2 (1 - f_M)^2 \sigma_M^2 \sigma_{X_F}^2 / \lambda_M^2}$$

  - Notice that $\mathrm{var}(m|P_F) = f_M \sigma_M^2 (1 - \rho_F^2)$ – more of m is revealed in more efficient markets
- Micro price efficiency is the proportion of variability in P_i that comes from s_i once P_F is known
- Similarly,

$$\rho_S^2 = \frac{f_S}{f_S + \gamma^2 (1 - f_S)^2 \sigma_S^2 \sigma_X^2 / \lambda_S^2}$$

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- Macro (micro) efficiency is increasing in:
  - f_M (f_S) – quality of information technology
  - λ_M (λ_S) – number of informed

Attention equilibrium: the micro/macro split

- Let $J \equiv \mathbb{E}[-\exp(-\gamma \tilde{W}_2)]$ where the expectation is taken over time 1 signals and time 2 cashflows
- We show that

$$J_M/J_U = \exp(\gamma c)\left(1 + \frac{f_M}{1-f_M}(1-\rho_F^2)\right)^{-\frac{1}{2}}$$
$$J_S/J_U = \exp(\gamma c)\left(1 + \frac{f_S}{1-f_S}\left(\frac{1}{\rho_S^2} - 1\right)\right)^{-\frac{1}{2}}$$

NOTE: Lower values indicate a utility gain (since J is negative)

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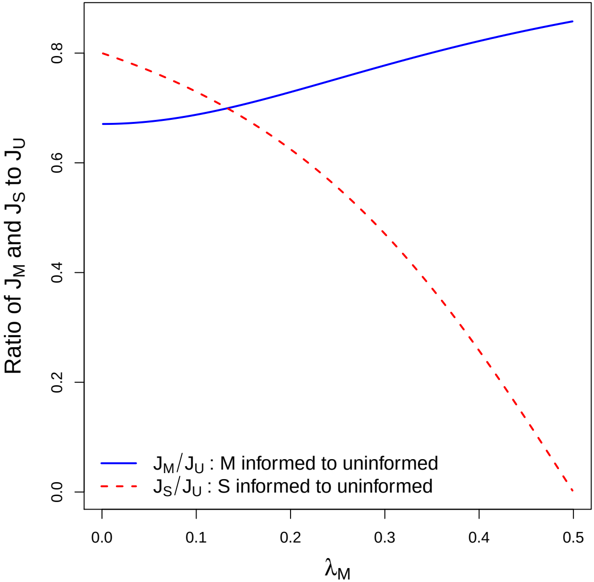
Lemma

Macro (micro) informed are strictly worse off as λ_M (λ_S) increases

- For a fixed λ_U, the attention equilibrium is determined by λ_M^* such that $J_M = J_S$

Interior equilibrium with $\lambda_U = 0.5$



Attention equilibrium solution

Proposition

The economy is either:

1. *At an interior equilibrium, in which case* $\lambda_M^* = \tilde{\lambda}_M \in [0, 1 - \lambda_U)$ *where* $\tilde{\lambda}_M$ *is available in closed form,*
2. *or,* $\lambda_M^* = 0$.

There are always some micro-informed investors: $\lambda_S^* > 0$.

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- Corollary:
  - Increase in micro risk ($\sigma_S \sigma_X$) [macro risk ($\sigma_M \sigma_{X_F}$)] pushes investors towards micro [macro] information

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- Corollary:
  - Increase in micro risk ($\sigma_S \sigma_X$) [macro risk ($\sigma_M \sigma_{X_F}$)] pushes investors towards micro [macro] information
  - An increase in risk aversion pushes investors towards micro information:

$$d\lambda_M^*/d\gamma < 0 \quad \text{(at interior equilibrium)}$$

Larger $\gamma \Rightarrow$ larger gains from noise traders, relative to trading against macro-uninformed

Is better information better for informed investors?

More precisely,

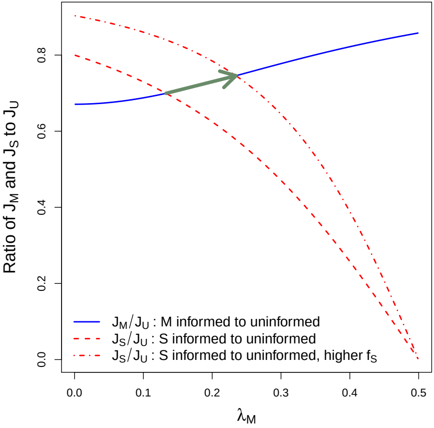
- If knowable micro fraction f_S increases, do micro-informed benefit?
- If knowable macro fraction f_M increases, do macro-informed benefit?
- How does changing f_S or f_M affect the equilibrium spilt of micro and macro informed?

Directions are not obvious because some of the information is revealed through prices

Micro and macro information are different!

Proposition

- *Better information (higher f_S) is always bad for micro informed;*
- *But better information (higher f_M) is good for macro informed as long as macro efficiency (ρ_F^2) is sufficiently low.*



- Better micro information reduces the risk premium that accrues to the micro informed
- Macro informed have the additional effect of gains from trade with the macro uninformed

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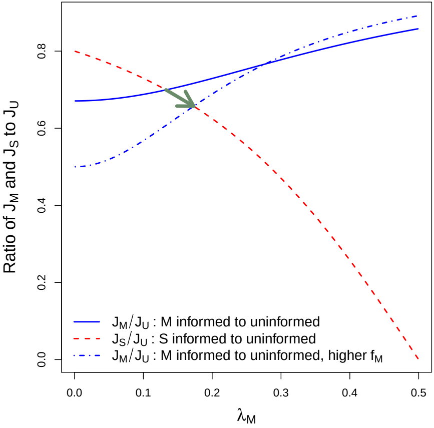

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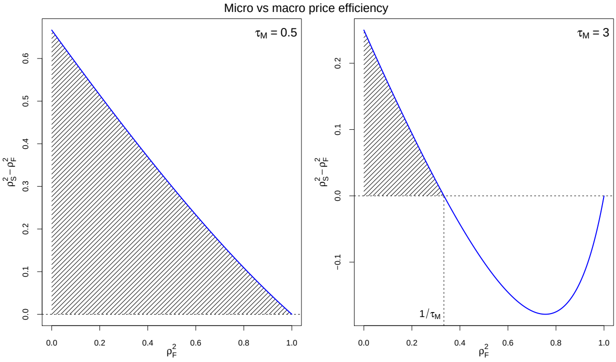
Micro vs macro price efficiency

Proposition

Let $\tau_M \equiv \dfrac{f_M/(1-f_M)}{f_S/(1-f_S)}$ *be the relative macro precision*

When $\tau_M < 1$ *markets are micro efficient* ($\rho_S^2 \geq \rho_F^2$). *Otherwise, there is always a range* $\rho_F^2 \in [0, 1/\tau_M]$ *of micro efficiency.*



Efficiency detail

Information equilibrium with cost for becoming informed

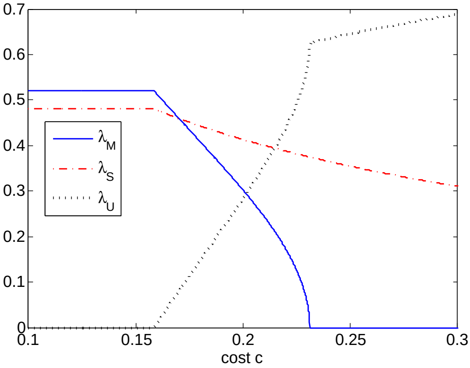
Information equilibrium with cost for becoming informed

- In an interior IE, with an information cost c: $J_U = J_M = J_S$
- At a boundary IE, no agent wants to switch

Proposition

An IE can have

1. *no uninformed agents (for low c),*
2. *all 3 agent types,*
3. *or micro and uninformed (for high c).*



Always have some micro informed, $\lambda_S > 0$

Effect of information costs on equilibrium

Proposition

As the cost c of becoming informed increases:

- *The number of uninformed increases*
- *Micro and macro price efficiency decrease*
- *The fraction $\Pi_M \equiv \frac{\lambda_M}{\lambda_M + \lambda_S}$ of macro informed falls*
  $\rightarrow$ *As c increases the fraction of informed who are micro informed increases*

In other words, being micro informed is particularly valuable when few investors are informed at all

Tendency towards micro efficiency – Summary

1. There are always micro informed in an attention or information equilibrium
2. On the other hand, we can have equilibria with no macro informed
3. As risk aversion grows, more investors become micro informed
4. $\rho_S^2 > \rho_F^2$ "a lot" of the time
5. Costlier information pushes a larger fraction of informed towards micro information

Why?

- With 0 macro informed J_M/J_U is small, but non-zero
- With 0 micro informed $J_S/J_U = 0$, so the 1st micro informed agent achieves infinite happiness

Attention equilibrium cycles

- Recall that attention equilibrium means
  - Total number informed remains fixed
  - Split between micro and macro informed is endogeous
- What happens if knowable fraction f_M changes with λ_M?
- In particular, suppose more macro information becomes available as more investors become macro informed
- Model this by letting f_M depend linearly on λ_M

Simple case: meta-tatonnement

→ Recall that an increase in f_M may help or hurt the macro informed

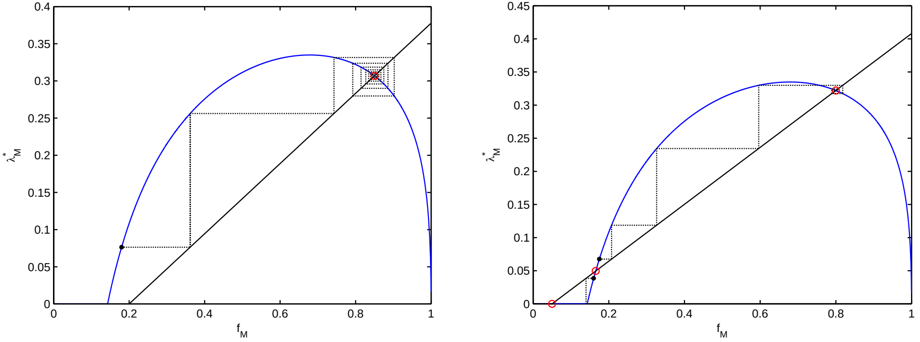
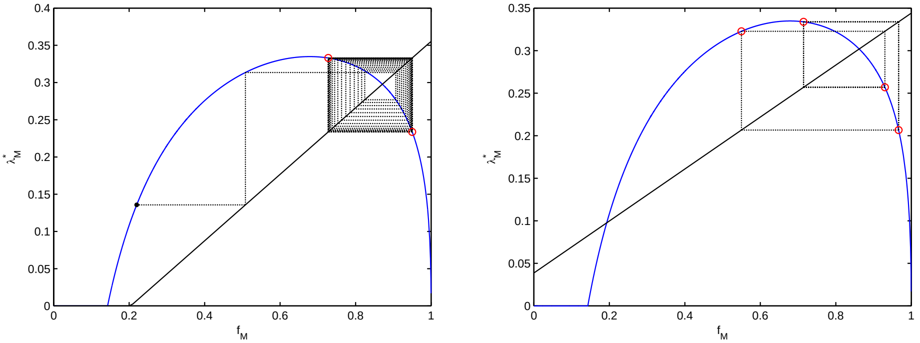


Figure: In each panel, the curved line is the mapping from f_M to λ^*_M, and the diagonal line is the response from λ_M to f_M.

Endogenous cycles

With no outside shocks, we can get cycles in the fraction of macro investors and the efficiency of macro prices!



This happens when line is flatter (f_M more responsive to λ_M)

We assume that investors cannot coordinate to avoid their impact on f_M

Cycles in macro and micro informed?

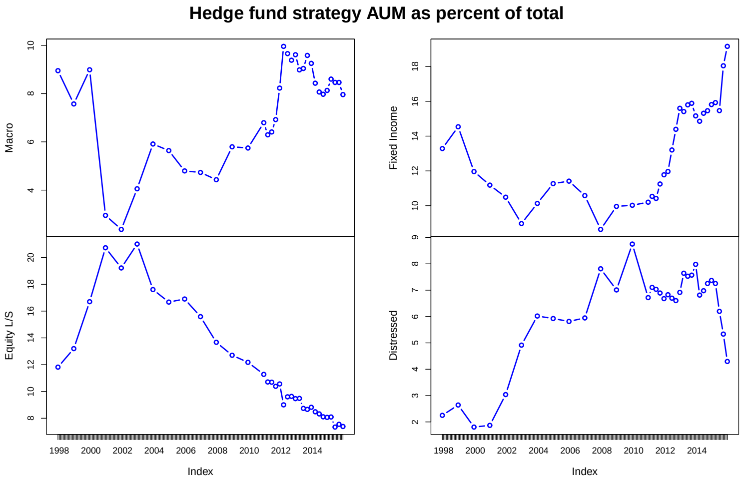


Figure: Percent of aggregate hedge fund assets under management devoted to different styles. Data is from *BarclayHedge* at `http://www.barclayhedge.com/research/indices/ghs/mum/HF_Money_Under_Management.html`.

Implications

Interesting implications for seemingly disparate phenomena observed in other work, including:

1. Common factor in idiosyncratic volatility
2. Excess volatility and comovement
3. Dynamics of money management industry
4. Information choice in recessions
5. Connection of trading volume to incentive to become informed

Idiosyncratic volatility

- In the model, idiosyncratic excess "returns" are given by

$$u_i - RP_i - \beta_i(M - RP_F) = \underbrace{\epsilon_i}_{\substack{\text{Unknowable portion} \\ \text{of dividend}}} + \underbrace{\gamma(1 - f_S)\sigma_S^2 X_i/\lambda_S}_{\substack{\text{Adjustment due to} \\ \text{idiosyncratic supply shock}}}$$

- Idiosyncratic volatility is

$$Vol_{idio}^2 = \sigma_{\epsilon_S}^2 \left(1 + \frac{\gamma^2 \sigma_{\epsilon_S}^2 \sigma_X^2}{\lambda_S^2}\right)$$

- Observations:
  - Anything that increases λ_S decreases idiosyncratic volatility
  - λ_S is a common factor in idiosyncratic volatility
    - Herskovic, Kelly, Lustig and Van Nieuwerburgh (2014): household income risk

Dividend and price process

Are stocks excessively volatile?

- Systematic volatility

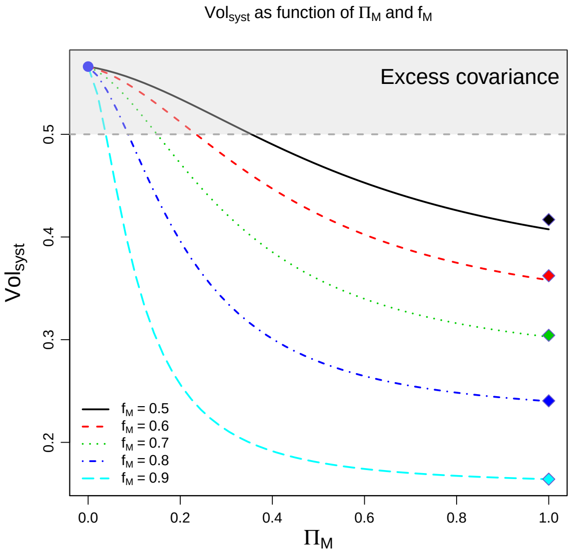
$$Vol^2_{syst} \equiv \mathrm{var}(M - RP_F) = \sigma^2_{\epsilon_M} + (1 - Rb_F)^2 \sigma^2_m + R^2 c_F^2 \sigma^2_{X_F}$$

  is known in closed form but is not as easily interpretable as Vol_{idio}
- We show numerically that Vol_{syst}
  - Falls with Π_M, the fraction of informed that are macro informed
  - Falls with f_M, the precision of the macro information technology
- Define excess volatility at the index level as

$$Vol^2_{syst} > \sigma^2_M$$

  - Have excess volatility when Π_M is low
- **Lemma:** Idiosyncratic volatility is excessive ($Vol^2_{idio} > \sigma^2_S$) if and only if markets are micro inefficient ($\rho^2_S < 1/2$)

Systematic volatility



Here $\sigma_M = 0.5$

Do stocks comove too much? (Peng and Xiong 2006, Veldkamp 2006)

- Fundamental covariance is

$$\mathrm{cov}(u_i, u_j) = \beta_i \beta_j \sigma_M^2$$

(S_i doesn't enter for large N)

- Return covariance is

$$\mathrm{cov}(u_i - RP_i, u_j - RP_j) = \beta_i \beta_j Vol_{syst}^2$$

(s_i and X_i do not enter for large N)

- Then excess covariance follows directly from excess index volatility
  - Which occurs when Π_M is low
- Same intuition applies to excess correlation, which reduces to

$$\frac{Vol_{syst}}{\sigma_M} > \frac{Vol_{idio}}{\sigma_S} \Longleftrightarrow \text{Excess correlation}$$

Dividend and price process

Information choices in recessions

- Kacperczyk, Van Niewerburgh, and Veldkamp (2016): related model with multiple assets
  - All informed investors identical but observe private signals
- They conclude that

> "...in recessions, the average amount of attention devoted to aggregate shocks should increase and the average amount of attention devoted to stock-specific shocks should decrease."

- They define recession as increased macro dividend volatility and increased risk aversion

Information choices in recessions

- In our setting, we can interpret this as asking how the fraction of macro informed λ_M^* changes with
  - increasing σ_M (increases λ_M^*, consistent)
  - increasing σ_S (decreases λ_M^*, potentially offsetting)
  - decreasing risk aversion γ (decreases λ_M^*, not consistent)
- Which predictions are correct? Why are they different?
- In both models, increasing σ_M and risk aversion decreases benefit of macro informed in trading against macro uninformed
- In our model, this also increases the benefit to the micro informed of trading against noise traders in individual stocks

Conclusion

- Novel model, solvable in closed form, for thinking about incentives to specialize in micro or macro information
- Many empirical implications
- Provides explanations for certain observed phenomena (some we didn't discuss today)
- Dynamic extension with endogenous information cycles? In progress

Thank you!

Market clearing, part i

- Aggregate holdings of the index fund q_F

$$q_F \equiv \underbrace{\lambda_U q_F^U}_{\text{uninformed}} + \underbrace{\lambda_M q_F^M}_{M \text{ informed}} + \underbrace{\frac{\lambda_S}{N}\sum_{i=1}^{N} q_F^i}_{i \text{ informed}}$$

- The market must clear for each stock i:

$$\underbrace{\frac{\lambda_S}{N}\sum_{j=1}^{N} q_i^j + \lambda_U q_i^U + \lambda_M q_i^M}_{\textit{Direct} \text{ demand for stock } i} + \underbrace{\frac{q_F}{N}}_{\substack{\textit{Indirect} \\ \text{demand}}} = \underbrace{\frac{1}{N}(X_F - \sum_{j=1}^{N} \beta_j X_j / N + X_i)}_{\text{Supply of stock } i}$$

Market clearing, part ii

- We assume and later prove: *Non-i informed have no direct demand for stock i*
  - Agents who are not micro-informed own stocks only via the index fund
  - This is how we would advise retail investors to act
  - We prove that this is true in two cases
- The market clearing condition reduces to

$$\underbrace{\lambda_S q_i^i}_{\textit{Direct}\text{ demand for stock } i} + \underbrace{q_F}_{\substack{\textit{Indirect}\\ \text{demand}}} = \underbrace{X_F - \sum_{j=1}^{N} \beta_j X_j / N + X_i}_{\text{Supply of stock } i} \quad \forall i \qquad (1)$$

Market clearing, part iii

- Rearranging the above expression, we conclude that

$$\lambda_S q_i^i = X_i + \xi$$

$$q_F = \underbrace{X_F - \frac{1}{N}\sum_j \beta_j X_j}_{\text{Insures that in total } X_F \text{ units of } M \text{ risk exist}} - \xi$$

for some ξ that does not depend on i

Proposition

The index fund price is the average of the stock prices ($P_F = \frac{1}{N}\sum_{i=1}^{N} P_i$) if and only if $\xi = 0$.

supply shocks

Agents' demands

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The i-informed demands are given by

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$$q_F^i = q_F^U - \beta_i q_i^i$$

Relationship of micro to macro price efficiency

- Can show that

$$\rho_S^2 = \frac{1}{1 + \tau_M(1 - \rho_F^2)}$$

- Which implies that

$$\rho_S^2 \to 1 \iff \rho_F^2 \to 1$$

and

$$\rho_S^2 \to \frac{1}{1 + \tau_M} \iff \rho_F^2 \to 0$$

Price efficiency main

Dividend and price process

- Recall that

$$P_i = \beta_i P_F + b_S s_i + c_S X_i$$
$$u_i = \beta_i M + S_i$$

Idiosyncratic volatility

Excess covariance