Uncertainty, Information Acquisition and Price Swings in Asset Markets

Antonio Mele
London School of Economics

Francesco Sangiorgi
Stockholm School of Economics

January 27, 2010

Uncertainty and ambiguity aversion

- **Risk**: randomness can be defined precisely

- **Knightian uncertainty** or **ambiguity** (Ellsberg, 1961): some events do not have a known, agreeable probability assignment.

- Ellsberg's paradox: individuals tend to prefer gambles with precise probabilities to gambles with unknown odds

  – Inconsistent with the expected utility model.

- Since ambiguity can affect significantly individual behavior, it should also be a significant determinant of equilibrium outcomes.

Uncertainty and asset markets

The mass downgrade of ABS securities on July 10 has placed us in a Knightian world in which investors don't know what they don't know...This is a world of Knightian uncertainty, not just risk, and many investor portfolios are concentrated in corners, as in "I don't want any ABS." Standard textbook models that ignore uncertainty predict that if risk goes up, portfolio composition should change, but should generally not go to zero! In a world of Knightian uncertainty, the best thing to do can be to leave the market!

Richard Clarida, October 2007

The main idea underlying this paper

- Financial markets might function very differently in a world of ambiguity than in a world of risk
- By now, the topic is well understood, in a framework of agents with **homogenous** and **given** information
- But we aren't all endowed with same information!
  - There coexist agents with and without ambiguity
- Moreover, the ambiguity perceived in the markets, might be endogenous
  - Degree of sophistication in certain derivative products might prompt investors to invest money to better understand their functioning

- But if enough investors understand these instruments and, hence, impinge their private information on prices, some other investors would not need to acquire information
  * The usual story: information acquisition and market efficiency

Purpose

- How does ambiguity affect the price formation process, in markets with asymmetric information?

$\Rightarrow$ We study asset markets with endogenous information acquisition, in which ambiguity averse investors face uncertainty related to the expected value of the fundamentals

Overview

We suggest uncertainty and ambiguity aversion lead to:

- increased incentives to acquire fundamental information
- in spite of a higher value of information, agents who are informed coexist with uninformed (and ambiguity averse) agents
- strategic complementarities in information acquisition, multiple equilibria, and history-dependent prices
- **Small changes in uncertainty may result in large asset price swings**

$\Rightarrow$ Uncertainty and ambiguity aversion lead to new channels for episodes of extreme price volatility, media frenzies and media glooms

The impact of an uncertainty shock

- We utilize the seventeen uncertainty shocks identified by Bloom (2009):

October 1962	Cuban missile crisis	October 1987	Black Monday
November 1963	Assassination of JFK	September 1990	Gulf War I
August 1966	Vietnam buildup	November 1997	Asian Crisis
May 1970	Cambodia and Kent State	September 1998	Russian, LTCM default
December 1973	OPEC I, Arab-Israel War	September 2001	9/11 terrorist attack
September 1974	Franklin National	July 2002	Worldcom and Enron
November 1978	OPEC II	February 2003	Gulf War II
March 1980	Afghanistan, Iran hostages	August 2007	Credit Crunch
August 1982	Monetary cycle turning point		

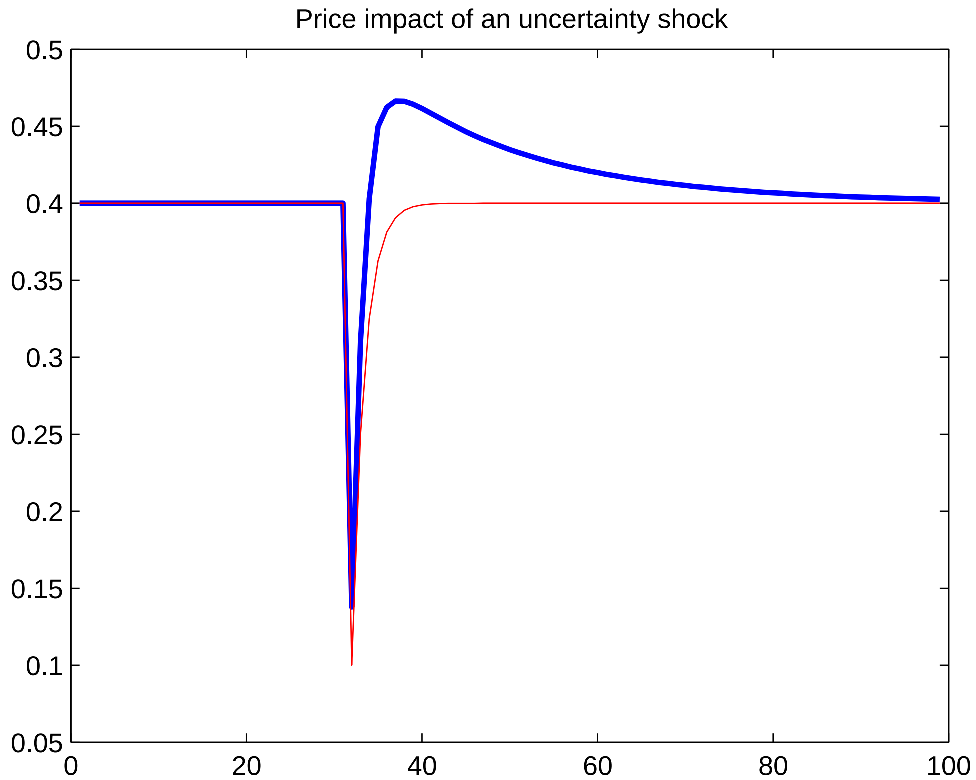
Stock market response to an uncertainty shock

	months after the shock					
	$(-1, 0)$	$+1$	$+2$	$+3$	$+4$	$+5$
estimate	-5.38	1.29	3.35	2.27	2.86	-0.19
t-stat	-7.03	1.19	3.09	2.09	2.63	-0.17

- VAR estimates of price impacts, in percentages. Control for a variety of things.
- So the aggregate stock market plummets after an uncertainty shock, although, then, it rebounds quite quickly, recovering in a matter of few months.
  - In many episodes such as the OPEC II shock (November 1978) or the 9/11 terrorist attack, the market does even overshoot its level before the occurrence of the shock.

- A simple explanation of these rallies is that uncertainty resolves quickly.
  - However, anecdotical evidence suggests uncertainty shocks persist for more than just two or three months.

- Our model provides an alternative explanation for the quick rebounds we observe in the data.
  - After an uncertainty shock, the market crashes, due to a friction in the market for information: although agents rush to acquire new information, the market for information cannot entirely satisfy the new demand but with some delay. As soon as this delay is absorbed, complementarities in information acquisition kick in, such that the information premium shrinks rapidly, accompanied by a quick price rebound.



Blue line: market with ambiguity aversion and endogenous information acquisition.
Red line: market with ambiguity aversion and no information

Complementarities in information acquisition

- *Why buying information that others have?* Two opposing forces
  - One, a standard strategic substitutability effect, by which an increase in the number of informed agents leads to more informative prices, which reduces the incentives to acquire information
  - Two, ambiguity aversion leads the uninformed agents to trade less and, in some cases, even exit the market, as the mass of informed agents increases.
    - This reduced market participation leads asset prices to be misaligned from the fundamentals, even more so than in markets without ambiguity, to the entire benefit of the informed agents.
- Therefore, in the presence of ambiguous fundamentals:

(i) information is more valuable than in a market without ambiguity

(ii) as the mass of informed agents increases, investors buy information that others have, to avoid being hurt from reduced market participation.

Related literature

On ambiguity and financial markets

- Dow and Werlang (92), Epstein and Wang (94; 95), Cao, Wang and Zhang (05), Easley and O'Hara (07), Anderson Ghysels and Juergens (08), Leippold, Trojani and Vanini (08), Epstein and Schneider (08), Caskey (08), Caballero and Krishnamurthy (08), Hansen and Sargent (08), Gagliardini, Porchia and Trojani (09), Bossaert, Ghirardato, Guarneschelli and Zame (09).

On strategic complementarities in information acquisition and financial markets

- Froot, Scharfstein and Stein (92), Veldkamp (06), Barlevi and Veronesi (00; 08), Chamley (08), García and Strobl (08).

Outline

1.1. Model

1.2. Information acquisition

1.3. Uncertainty and price swings

1.4. Infinite horizon market

1.1. Model

Agents, assets and information

Static

- Risky asset, with payoff equal to $f = \theta + \epsilon$, where $\theta \sim N(\mu_0, \omega_\theta)$ and $\epsilon \sim N(0, \omega_\epsilon)$
- Riskless asset in perfectly elastic supply
- The asset supply is $z \sim N(\mu_z, \omega_z)$
- CARA utility, risk aversion τ
- Continuum of agents, a fraction λ of informed agents observe θ at cost c; $1 - \lambda$ are uninformed

Depart from Grossman and Stiglitz (1980), in that:

- All agents are ex-ante uncertain about the expected value of the fundamental, μ_0
- Agents believe $\mu_0 \in [\underline{\mu}, \bar{\mu}]$, where $\bar{\mu} - \underline{\mu} = \Delta\mu$ measures the "size" of ambiguity
- Ambiguity aversion: Maxmin expected utility representation of Knightian uncertainty, as in Gilboa and Schmeidler (1989)

Infinite horizon market

- Asset payoff as of time t is $f_t = \theta_t + \epsilon_t$, where θ_t denotes its "persistent" component,

$$\theta_{t+1} = (1 - \rho_\theta)\, \mu_t + \rho_\theta \theta_t + \sigma_\theta \theta_t \eta_{t+1}, \quad \epsilon_t \sim NID\,(0, \omega_\epsilon)\,, \quad \eta_t \sim NID\,(0,1)\,,$$

  where μ_t is IID from some distribution from $[\bar{\mu}_t, \underline{\mu}_t]$, and the truth, μ_0, is symmetrically located around $\bar{\mu}_t$ and $\underline{\mu}_t$, $\underline{\mu}_t = \mu_0 - \Delta\mu_t$ and $\bar{\mu}_t = \mu_0 + \Delta\mu_t$.

- Once an uncertainty shock hits the market, it is absorbed quickly but gradually, such that uncertainty reverts to its long-run value $\overline{\Delta\mu}$,

$$\Delta\mu_{t+1} = \left(1 - \rho_{\Delta\mu}\right) \overline{\Delta\mu} + \rho_{\Delta\mu} \Delta\mu_t + \sigma_{\Delta\mu} J_{t+1},$$

  where J_t is the uncertainty shock, which is II binomially distributed with a "small" frequency p.

- We assume the market of information is sticky, in that it takes time for this market to entirely absorb new demand for information. In each period, then, this market satisfies only a fraction $(1-\alpha)$ of agents who wish to purchase information:

$$\lambda_t = \alpha\lambda_{t-1} + (1-\alpha)\,\lambda_t^*,$$

where λ_t^* denotes the fraction of agents who would become informed in the absence of any friction.

Portfolio choice

We consider the static problem, first.

Informed agents

- Upon observing θ, informed agents resolve their ambiguity straight away. Therefore, they choose portfolio holdings x_I to maximize

$$v_I(\theta) = E\left(-e^{-\tau W_I} \middle| \theta, p\right),$$

where $W_I = (f - p)\, x_I - c$ and p denotes the observed asset price.

- The solution to the informed agents' problem is

$$x_I(\theta, p) = \frac{E(f|\,\theta, p) - p}{\tau Var(f|\,\theta, p)} = \frac{\theta - p}{\tau \omega_\epsilon}.$$

Uninformed agents

- Uninformed agents face ambiguity toward μ, and choose portfolio holdings x_U so as to maximize:

$$v_U(p) = \min_{\mu} E_{\mu}\left(-e^{-\tau W_U}\middle| p\right) = -e^{-\tau \min_{\mu} E_{\mu}(W|p)+\frac{1}{2}\tau^2 var(W|p)},$$

where $W_U = (f-p)\, x_U$.

- The solution to the uninformed agents' problem is

$$x_U(p) = \begin{cases} \dfrac{E_{\underline{\mu}}(f|p) - p}{\tau Var(f|p)}, & \text{for } p < E_{\underline{\mu}}(f|p) \\ 0, & \text{for } p \in \left[E_{\underline{\mu}}(f|p), E_{\bar{\mu}}(f|p)\right] \\ \dfrac{E_{\bar{\mu}}(f|p) - p}{\tau Var(f|p)}, & \text{for } p > E_{\bar{\mu}}(f|p). \end{cases}$$

- Uninformed agents do not participate in the asset market if $p \in \left[\underline{p}, \bar{p}\right]$, where the cutoffs $\underline{p}$ and $\bar{p}$ solve a fixed point problem:

$$E_{\underline{\mu}}\left(f|\underline{p}\right) = \underline{p} \quad \text{and} \quad E_{\bar{\mu}}(f|\bar{p}) = \bar{p}.$$

Equilibrium in the asset market

Price function

- Conjecture the price function is,

$$P(\theta, z) = P(s(\theta, z)),$$

where $s(\theta, z)$ is the compound signal,

$$s(\theta, z) = \frac{\lambda}{\tau\omega_\epsilon}\theta - (z - \mu_z).$$

- The market clearing condition can be rearranged as:

$$(1-\lambda)\, x_U(p, P(\cdot)) - \frac{\lambda}{\tau\omega_\epsilon}p = -s(\theta, z) + \mu_z$$

$\Rightarrow$ The compound signal is observationally equivalent to the equilibrium price.

Proposition 1. *The price is piecewise linear in the compound signal,*

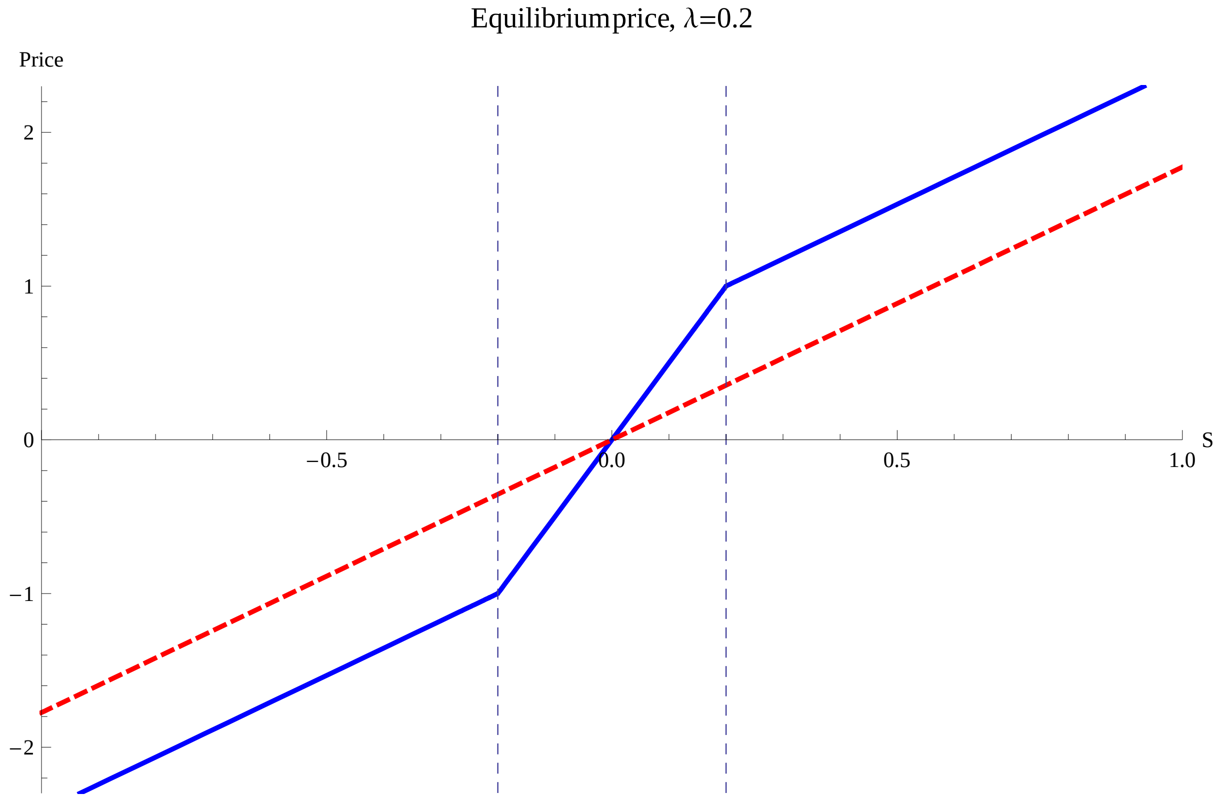
$$P(s) = \begin{cases} \underline{a} + bs, & \text{for } s < \underline{s} \\ a + \dfrac{\tau\omega_\epsilon}{\lambda} s, & \text{for } s \in [\underline{s}, \bar{s}] \\ \bar{a} + bs, & \text{for } s > \bar{s} \end{cases}$$

The threshold values for the compound signal, $\underline{s}, \bar{s}$, satisfy:

$$\bar{s} = \frac{\lambda}{\tau\omega_\epsilon}\bar{\mu} + \frac{\omega_s}{\omega_z}\mu_z, \quad \bar{s} - \underline{s} = \frac{\lambda}{\tau\omega_\epsilon}\Delta\mu.$$

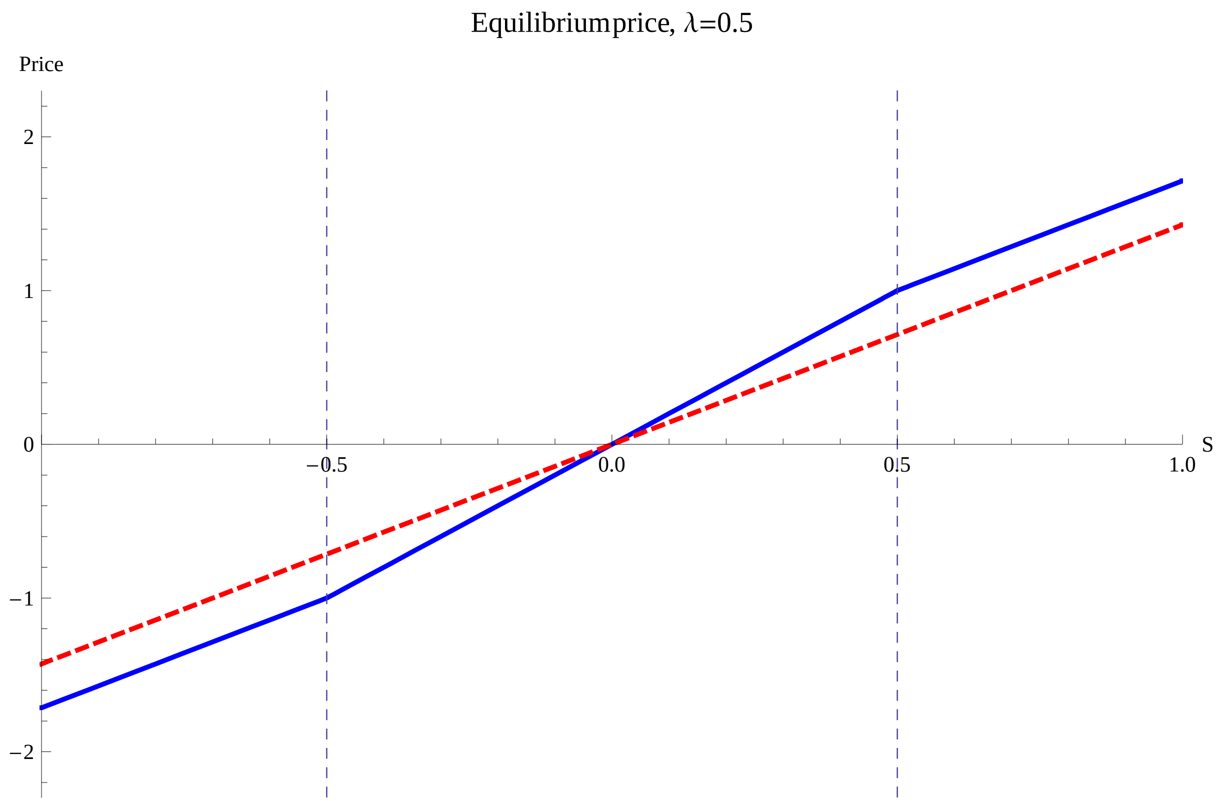
Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = 1$, $\mu_z = 0$

Red dashed line: $\Delta\mu = 0$, Blue solid line: $\Delta\mu = 2$



Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = 1$, $\mu_z = 0$

Red dashed line: $\Delta\mu = 0$, Blue solid line: $\Delta\mu = 2$



1.2. Information acquisition

Choices

- Analyze how ambiguity affects the incentives to acquire fundamental information: solve for the endogenous fraction of informed agents, λ
- As in Grossman and Stiglitz (1980), all agents need to evaluate the ex-ante expected utilities, before deciding whether to become informed
- The process of info acquisition differs from Grossman and Stiglitz, in that *all* agents are ex-ante ambiguity averse, which leads them to assess future events at the worst-case scenario, or

$$\mathcal{U}_I(c, \lambda) = \min_\mu E_\mu [v_I(\theta, s)] \quad \text{(Would-be } \textbf{informed}\text{)}$$

$$\mathcal{U}_U(\lambda) = \min_\mu E_\mu [v_U(s)] \quad \text{(Would-be } \textbf{uninformed}\text{)}$$

where v_I and v_U are the interim utilities – i.e. the utilities conditioned upon acquiring information (v_I) or not acquiring information (v_U)

Uninformed agents

- The ex-ante expected utility for a would-be uninformed agent is:

$$\mathcal{U}_U(\lambda) = \min_{\mu} E_{\mu}\left[v_U\left(s\left(\theta, z\right)\right)\right],$$

where $v_U(s)$ is the interim utility for the uninformed agents, defined as

$$v_U(s) = -e^{-\tau \mathcal{C}_U(s)}, \quad \mathcal{C}_U(s) = \min_{\mu} E_{\mu}\left(W_U | s\right) - \frac{1}{2}\tau var\left(W_U | s\right).$$

- The compound signal s is normally distributed, with mean $\mu_s(\mu)$ and variance ω_s, where,

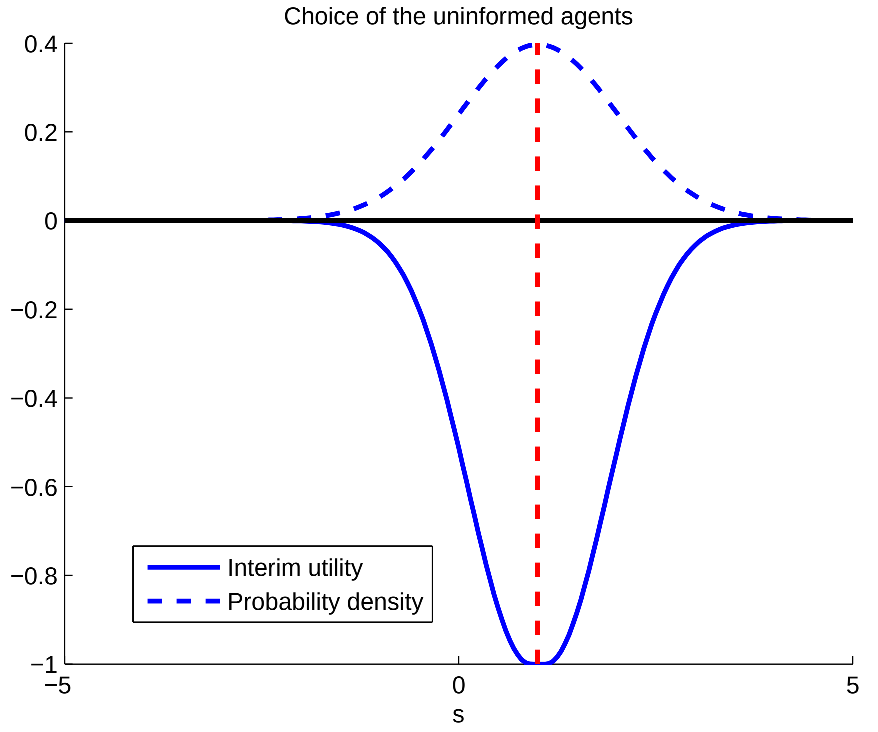
$$\mu_s(\mu) \equiv \frac{\lambda}{\tau\omega_{\epsilon}}\mu.$$

- We have a closed-form expression for the unconditional expectation of the interim utility:

$$E_\mu\left[v_U(s)\right]=\int_{-\infty}^{\infty} v_U(s)\, d\Phi\left(s;\mu_s(\mu),\omega_s\right),$$

where $\Phi(\cdot;\mu,\omega)$ denotes the cumulative function of a normal variate with mean μ and variance ω.

Proposition 2. *The ex-ante expected utility of the uninformed agents,* $\mathcal{U}_U(\lambda, \mu)$, *is minimized at* $\mu_U(\lambda) = \min\left\{\frac{\tau\omega_\epsilon}{\lambda}\frac{\omega_s}{\omega_z}\mu_z, \bar{\mu}\right\}$.



Informed agents

- The ex-ante expected utility for a would-be informed agent is,

$$\mathcal{U}_I(c,\lambda) = \min_{\mu} E_\mu\left[v_I(\theta, s(\theta, z))\right],$$

where $v_I(\theta, s)$ is the interim utility for any informed agent, defined as

$$v_I(\theta, s) = -e^{-\tau(\mathcal{C}_I(\theta,s)-c)}, \quad \mathcal{C}_I(\theta, s) = \frac{1}{2}\frac{(\theta - P(s))^2}{\tau\omega_\epsilon},$$

and the equilibrium price, $P(s)$, is as in Proposition I.

- We have a closed-form expression for the unconditional expectation of the interim utility,

$$E_{\mu}\left[v_I\left(\theta, s\right)\right] = e^{\tau c}\sqrt{\frac{\omega_{\epsilon}}{\omega_{f|s}}} \cdot E_{\mu}\left[\bar{v}_I\left(s;\mu\right)\right],$$

where $\bar{v}_I\left(s;\mu\right)$ is some negative function.

Equilibrium in the market for information

The indifference condition

- An equilibrium with endogenous information acquisition is defined as a fraction of informed agents, $\lambda^* \in [0,1]$, such that

$$\mathcal{U}_I(c,\lambda^*) = \mathcal{U}_U(\lambda^*)$$
$$\Longleftrightarrow$$
$$\frac{\mathcal{U}_I(c,\lambda^*)}{\mathcal{U}_U(\lambda^*)} = \underbrace{e^{\tau c}\sqrt{\frac{Var(f|\theta,p)}{Var(f|p)}}}_{\text{Grossman-Stiglitz effect}} \cdot \underbrace{A(\lambda^*,\Delta\mu)}_{\text{Ambiguity aversion effect}} = 1,$$

where

$$A(\lambda,\Delta\mu) = \frac{E_{\mu_I}[\bar{v}_I(s;\mu)]}{E_{\mu_U}[v_U(s)]}, \qquad A(\lambda,0) = 1.$$

The value of information

- Ambiguity and the incentives to purchase fundamental information:

Proposition 3. *Information is more valuable in a market with ambiguous fundamentals ($\Delta\mu > 0$) than in a market without ambiguity ($\Delta\mu = 0$).*

- The mechanism:

(i) Uninformed agents experience lower utility because of the reduced participation in the market

  * Portfolio choice reflects the worst case scenario expected returns $\Rightarrow$ *for any* realization of the fundamentals, uninformed investors trade less than if there was no ambiguity.

(ii) Informed investors exploit the “mispricing” induced by the presence of uninformed investors.

  * Informed investors can buy at lower prices and sell at higher prices, thus making higher profits.

$\Rightarrow$ More agents choose to acquire fundamental information.

1.3. Uncertainty and price swings

Strategic complementarities in information acquisition

Proposition 4. *Let $\Delta\mu > 0$. Then, there exists $\bar{\mu}_z > 0$ such that there are* ***strategic complementarities in information acquisition*** *for all $\mu_z > \bar{\mu}_z$.*

As λ increases:

1 standard strategic substitutability effect

   – more informed trading increases price efficiency, which reduces the informational advantage of the informed above the uninformed agents (standard strategic substitutability effect)

2 **Stock market participation by uninformed agents decreases (on a per-capita basis), making uninformed agents worse off from an ex-ante perspective**

   – Novel, related to ambiguity

Intuition:

(i) The utility of both informed and uninformed agents increases with μ_z.

- As $\mu_z \uparrow$, the price $\downarrow$, mechanically. That is, the price deviates from the fundamentals, to the benefit of the agents who buy (more, and) cheap.

(ii) Uninformed investors' utility is reduced with ambiguity, because of a reduced stock market participation

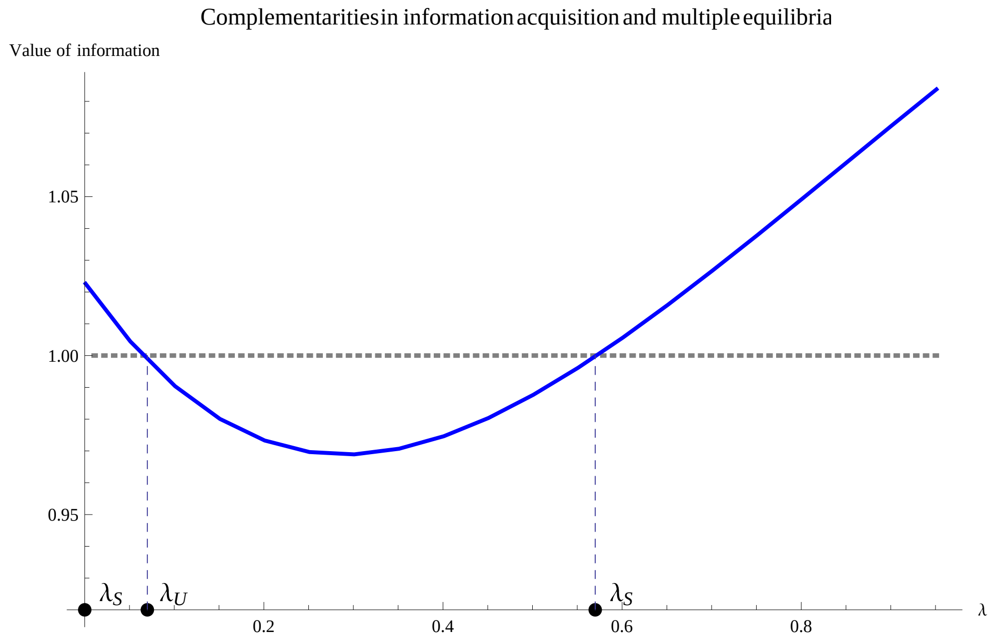
(iii) The extent of this participation is decreasing in the risk-bearing capacity of the informed side of the market

- Granted, the utility informed investors get, decreases with their mass
  - But, if the average asset supply, μ_z, is sufficiently large, such a reduction is less than the welfare reduction the uninformed experience in (iii)
    * If μ_z is large, and λ is low, then, the uninformed agents are buyers most of the time, and prices will be particularly low, reflecting the pessimistic behavior of the uninformed agents.
    * The worst-case scenario for an agent considering, ex ante, to become informed, then, is that the expected payoffs are indeed low (i.e. $\mu_I = \underline{\mu}$), so that the perceived mispricing (and the benefits from it) vanish.
    * If the ex-ante perceived mispricing is low to start with, then, as λ increases, the shrinkage in the ex-ante utility of the informed investors is weak, compared to the loss in the ex-ante utility of the uninformed.

Multiple equilibria

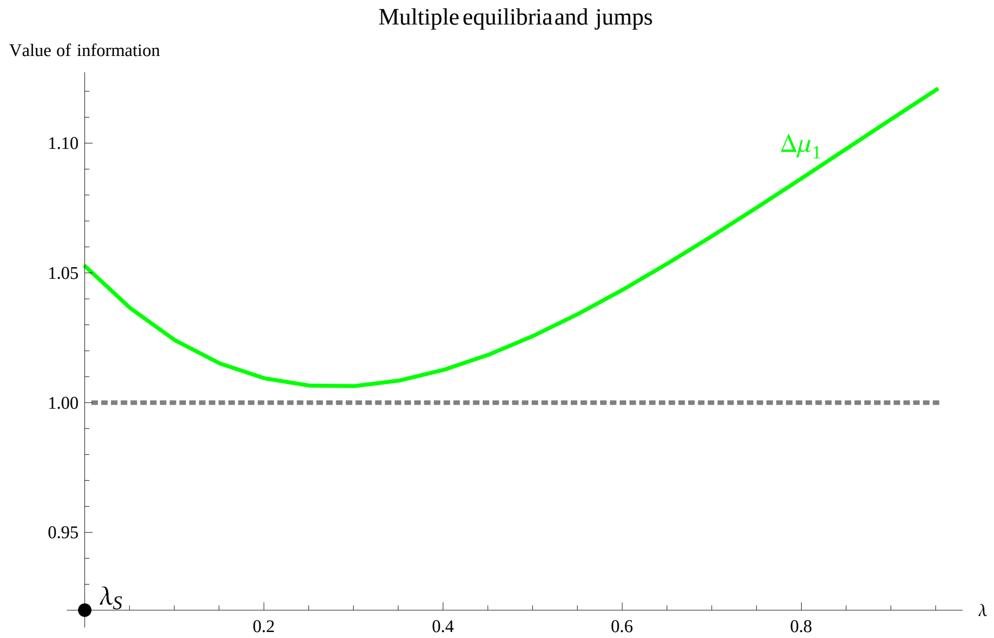
Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = \mu_z = 1$, $c = 0.5$

$$\Delta\mu = 1$$



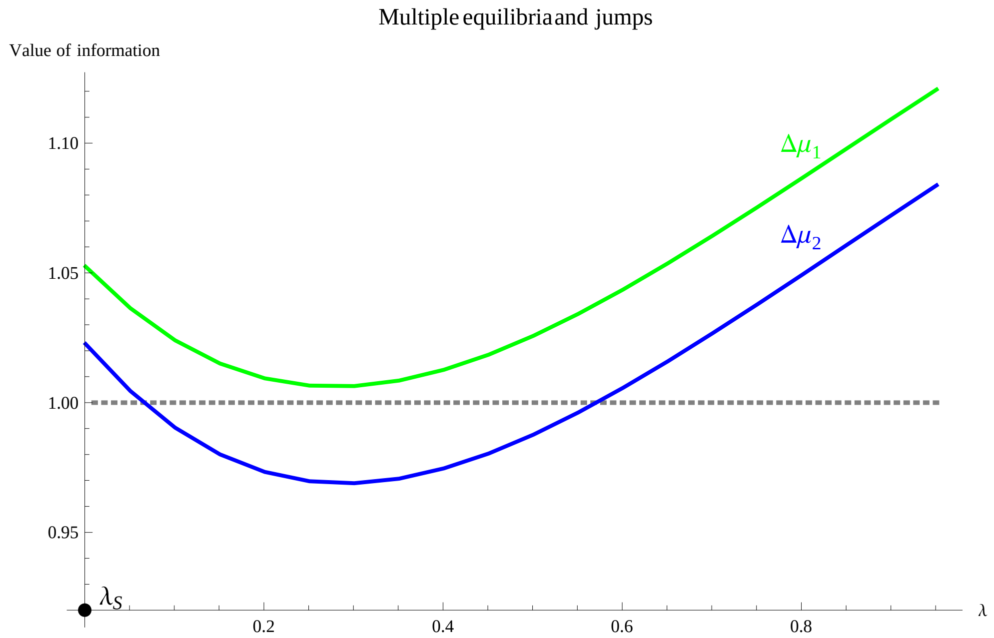
Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = \mu_z = 1,\ c = 0.5$

$$\Delta\mu_1 = 0.8$$



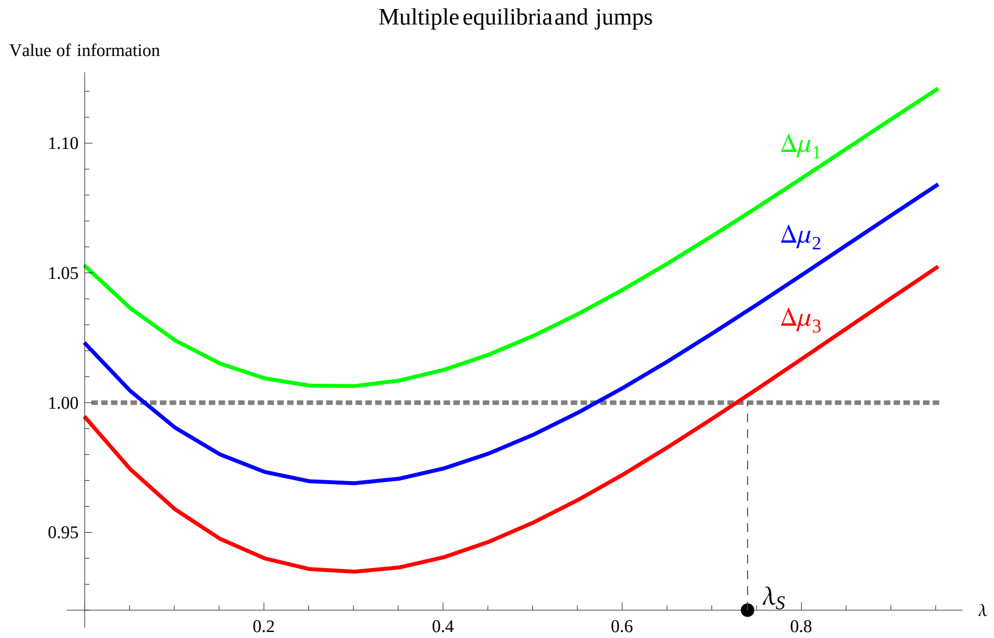
Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = \mu_z = 1$, $c = 0.5$

$$\Delta\mu_1 = 0.8 \quad \Delta\mu_2 = 2$$



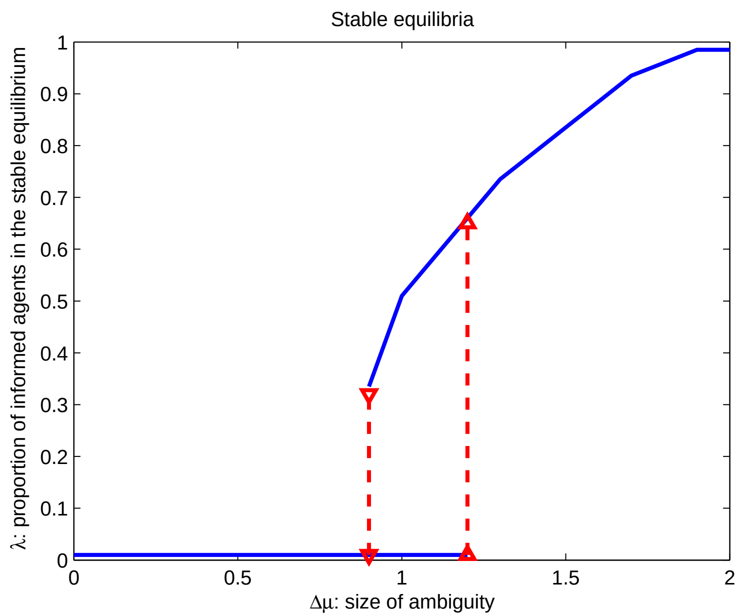
Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = \mu_z = 1$, $c = 0.5$

$$\Delta\mu_1 = 0.8 \quad \Delta\mu_2 = 2 \quad \Delta\mu_3 = 2.2$$

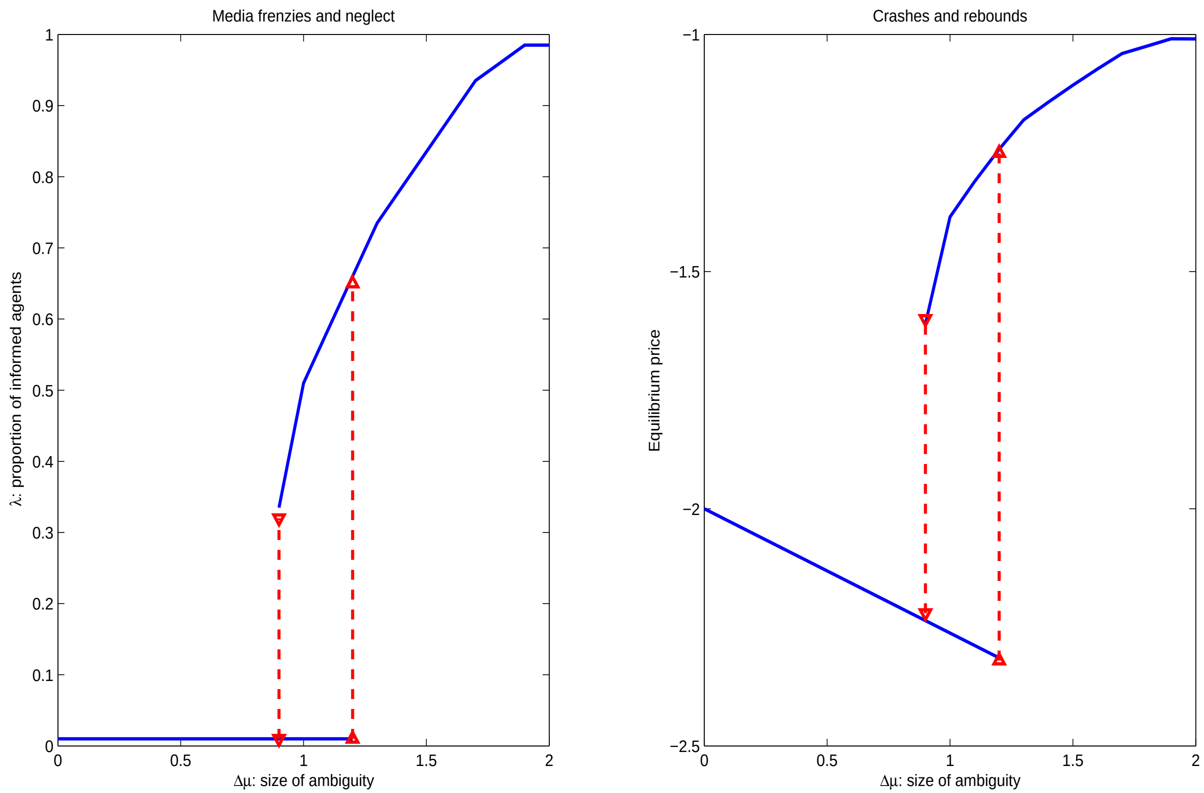


Jumps in information acquisition

Parameter values: $\omega_\theta = \omega_\epsilon = \omega_z = \tau = 1$, $c = 0.5$



Price swings

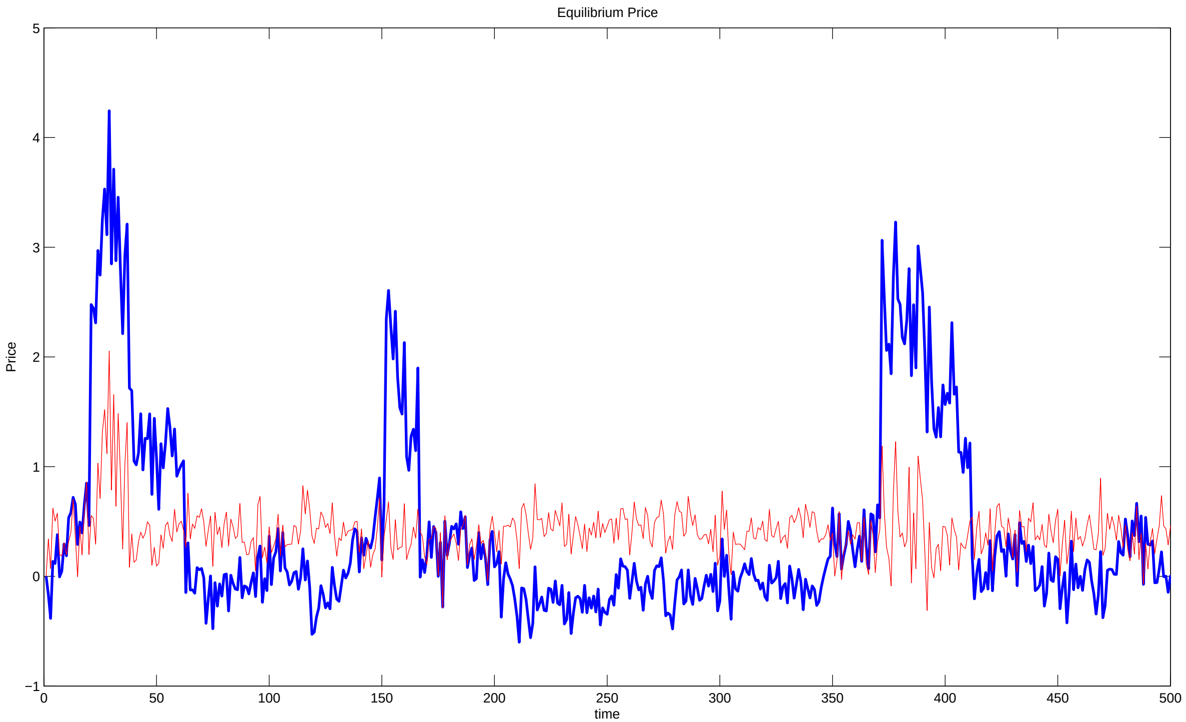


1.4. Infinite horizon market

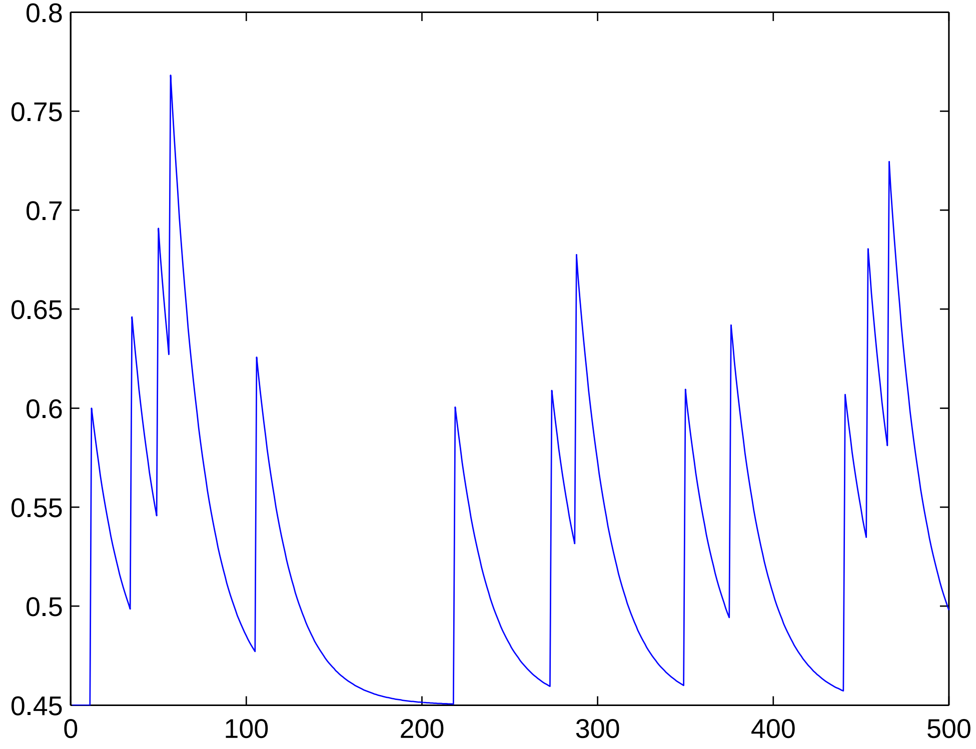
- Setup: Goto slide no. 17

- Solve for the equilibrium price

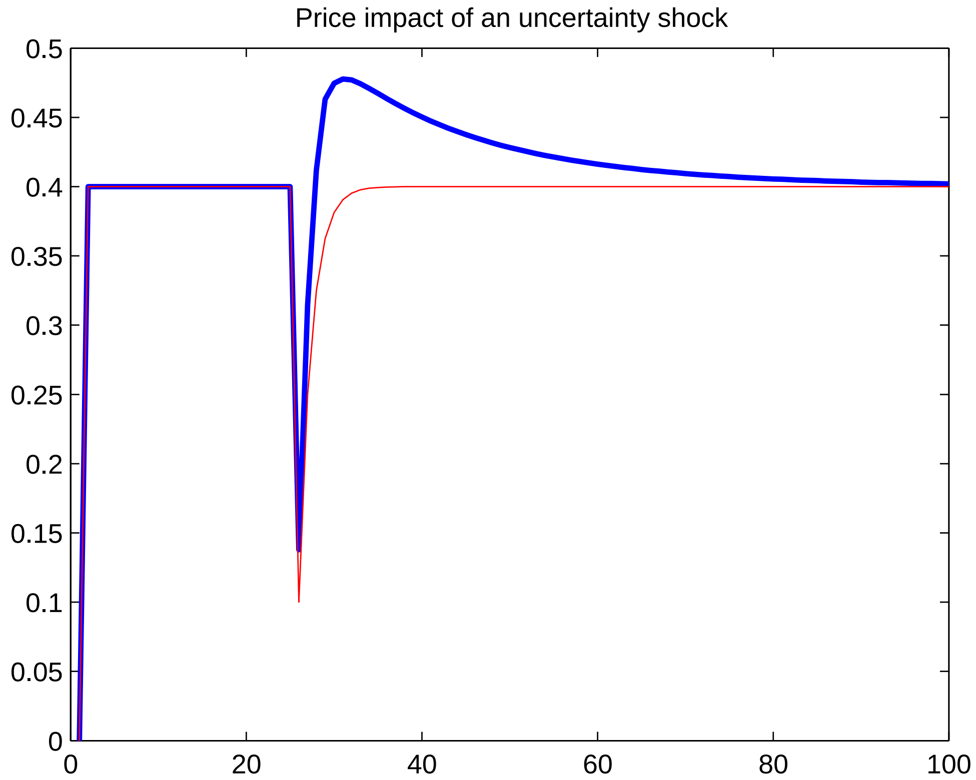
Freezing uncertainty



Simulation of uncertainty shocks



The impact of an uncertainty shock



Conclusion

- Model information acquisition process in a world of Knightian uncertainty.
- Strategic complementarities in information acquisition.
- Price multiplicity as an extreme form of excess volatility
- The impact of an uncertainty shock.