Dynamic Asset Pricing Models: Recent Developments

Day 2. Habit Formation Models and Economic Activity

Pietro Veronesi

Graduate School of Business,
University of Chicago
CEPR, NBER

Bank of Italy: June 2006

Overview

1. Review of Campbell and Cochrane (1999) Habit Persistence Model
2. Develop Santos and Veronesi (2006) model.
    - Explain Asset Pricing Puzzles: Equity Premium, Volatility, Risk free rate, Predictability.
3. The Pastor and Veronesi (2005) Habit Persistence Model
4. Habit Persistence and Economic Uncertainty:
    - Rationalize of the 1990s "Bubble"
    - Rationale IPO Waves

External Habit: Campbell and Cochrane (1999).

- Constantinides (1990), Detemple and Zapatero (1991), Campbell and Cochrane (1999) and others use the following representation of habit preferences.
- The representative agent maximizes

$$E\left[\int_0^\infty u\left(C_t, X_t, t\right) dt\right], \tag{1}$$

- where the instantaneous utility function is give by

$$u\left(C_t, X_t, t\right) = \begin{cases} e^{-\rho t} \frac{\left(C_t - X_t\right)^{1-\gamma}}{1-\gamma} & \text{if } \gamma > 1 \\ e^{-\rho t} \log\left(C_t - X_t\right) & \text{if } \gamma = 1 \end{cases} \tag{2}$$

- X_t is a habit level.
- Campbell and Cochrane (1999) consider X_t as an *external* habit, rather than internal.
  - Catching up with the Joneses.

A Problem

- The model above is not homogeneus, and thus it is hard to work with.
- One additional problem is that in endowment economies, for standard specification of X_t we cannot guarantee

$$C_t > X_t$$

- For instance, assume that consumption (endowment) follows the geometric Brownian motion

$$\frac{dC_t}{C_t} = \mu_c dt + \sigma_c dB_t$$

- Assume also X_t is just a weighted average of past consumption:

$$X_t = X_0 e^{-\alpha t} + \alpha \int_0^t e^{-\alpha(\tau - t)} C_\tau d\tau$$

- Ito's Lemma implies

$$dX = \alpha \left(C_t - X_t \right) dt$$

The Surplus Consumption Ratio Dynamics

- Consider now the following quantity

$$S_t = \frac{C_t - X_t}{C_t} \tag{3}$$

- Campbell and Cochrane (1999) call S_t the *Surplus Consumption Ratio*.
- Clearly, we must have $S_t \in [0, 1]$
- However, if we apply Ito's Lemma to S_t we find

$$dS = k\left(\overline{S} - S_t\right) dt + \lambda\left(S_t\right) dB_t \tag{4}$$

- where

$$k \;=\; \mu_c - \alpha - \sigma_c^2; \;\; \overline{S} = \left(\mu_c - \sigma_c^2\right)/k; \;\; \lambda\left(S_t\right) = \left(1 - S_t\right)$$

- Note that S_t is:
  - Mean reverting: This is a consequence of habit formation and the fact that X_t is slow moving.
  - Perfectly correlated with innovations to consumption growth, given by dB_t.
  - The volatility of surplus is time varying.

The Surplus Consumption Ratio Dynamics

- Note also that S_t is bounded above:
  - when S_t reaches 1, the diffusion disappears, and the drift is negative.
  - Thus, S_t is dragged down.

- However, nothing stops S_t from going below zero:
  - When $S_t = 0$, the diffusion is still positive (and in fact large).
  - Although the drift is also positive under the sensible assumption that $\mu_c > \sigma_c^2$, there is a non-zero probability that $S_t \leq 0$.
- This event of course is inconsistent with the preference specification.

Campbell and Cochrane Solution

- Campbell and Cochrane (1999) had a great intuition:
  - Specify the mean reverting dynamics for *log* surplus $s_t = \log(S_t)$
  - Specify $\lambda(s_t)$ in a way to ensure $S_t = exp(s_t) \in [0, 1]$.
- In addition, they specified $\lambda(s_t)$ to obtain specific properties of the interest rate process r_t (e.g. constant!)
- Unfortunately, their specification does not yield closed form solutions for prices.
- I therefore follow Santos and Veronesi (2005), which generalizes the setting in Menzly, Santos, Veronesi (2004) to the power utility case.
- Consider first the stochastic discount factor implied by the habit model

$$\pi_t = e^{-\rho t} \frac{\partial u\left(C_t, X_t\right)}{\partial C_t} = e^{-\rho t}\left(C_t - X_t\right)^{-\gamma} = e^{-\rho t} C_t^{-\gamma} S_t^{-\gamma}$$

- The surplus consumption ratio acts as a "preference shock", as it changes the curvature of the utility function: γS_t^{-1}.

Santos and Veronesi (2006) model

- Since S_t is naturally mean reverting, Campbell and Cochrane (1999) consider the particular monotonic transformation $s_t = \log(S_t)$ and model s_t as mean reverting.
- Santos and Veronesi (2006) use a different monotonic transformation, namely

$$G_t = S_t^{-\gamma} \tag{5}$$

- Assume then that G_t is mean reverting

$$dG_t = k\left(\overline{G} - G_t\right)dt - \alpha\left(G_t - \lambda\right)\sigma_c dB_t \tag{6}$$

- Note the following:
  1. G_t is mean reverting, like S_t.
  2. G_t is *negatively* perfectly correlated with innovations to consumption dB_t.
  3. G_t is bounded below by $\lambda > 1$. That is, we restrict $C_t > X_t$ at all times.
- These are the same properties of Campbell and Cochrane (1999).

Interest Rate in SV model

- Since $\pi_t = e^{-\rho t} C_t^{-\gamma} G_t$, the SDF is given by

$$\frac{d\pi_t}{\pi_t} = -r_t^f dt - \sigma_\pi dB_t,$$

- The risk free rate is given by

$$r_t^f = \rho + \gamma\mu_c - \frac{1}{2}\gamma(\gamma+1)\sigma_c^2 + k\left(1 - \overline{G}S^\gamma\right) - \gamma\alpha\left(1 - \lambda S^\gamma\right)\sigma_c^2 \tag{7}$$

- **Comments:**

1. The first three terms in r_t are standard.
2. The fourth term $k\left(1 - \overline{G}S^\gamma\right)$ represents the intertemporal substitution effect

   Low S_t $\rightarrow$ high expected S_τ in future $\rightarrow$ Borrow to increase C_t $\rightarrow$ r_t high

3. The last term $-\gamma\alpha\left(1 - \lambda S^\gamma\right)$ represents an additional precautionary savings term:

   Low S_t $\rightarrow$ higher probability $C_\tau = X_\tau$ in the future $\rightarrow$ Save more today $\rightarrow$ r_t low

4. Campbell and Cochrane (1999) choose parameters so that these two effects cancel each other $\rightarrow$ constant r_t

The Market Price of Risk in SV model

- The volatility of the stochastic discount factor is given by

$$\sigma_\pi = [\gamma + \alpha (1 - \lambda S_t^\gamma)] \sigma_c. \tag{8}$$

- σ_π now depends on S_t^γ

Low S_t $\longrightarrow$ higher curvature of the utility function γS_t^{-1} $\longrightarrow$
$\longrightarrow$ Higher aversion to risk $\longrightarrow$ Higher price of risk

Stock Prices in SV model

- Coming to the stock price of a consumption claim, we have

$$P_t = E_t\left[\int_t^\infty \left(\frac{\pi_\tau}{\pi_t}\right) C_\tau d\tau\right] \tag{9}$$

- Substituting, we obtain

$$P_t = C_t^\gamma S^\gamma E_t\left[\int_t^\infty e^{-\rho(\tau-t)} C_\tau^{1-\gamma} G_\tau d\tau\right] \tag{10}$$

- The solution is in closed form

$$P_t = C_t\left(b_1 + b_2 S_t^\gamma\right)$$

- where

$$b_1 = \frac{1}{\alpha_1}; \quad b_2 = \frac{k\overline{G} + \alpha(1-\gamma)\lambda\sigma_c^2}{\alpha_1\alpha_2}$$

with

$$\alpha_1 = \rho - (1-\gamma)\mu_c + \frac{1}{2}(1-\gamma)\gamma\sigma_c^2 + k + \alpha(1-\gamma)\sigma_c^2$$

$$\alpha_2 = \rho - (1-\gamma)\mu_c + \frac{1}{2}(1-\gamma)\gamma\sigma_c^2$$

Properties of Stock Prices in SV model

- The implications for

$$P_t/C_t = b_1 + b_2 S_t^{\gamma}$$

  is straightforward:

  - a higher surplus consumption ratio S_t translates in lower risk preference, and thus a higher price.

- Intertemporal smoothing hits here too.
  - From the form of b_1 and b_2, a high consumption growth μ_c translates into a lower P/C ratio, as we saw with learning.
  - Therefore, learning abour μ_c, for instance, will generate the same problem it did for the standard power utility case.
    - Higher uncertainty $\Longrightarrow$ lower equity premium

Return Volatility and Equity Premium

- What about the volatility and the equity premium?
- By using Ito's Lemma, we have

$$E_t\left[dR_t\right] = \left(\gamma + \alpha\left(1 - \lambda S_t^{\gamma}\right)\right)\sigma_R\left(S_t\right)\sigma_c$$

$$\sigma_R\left(S_t\right) = \left[1 + \frac{b_2 S_t^{\gamma}\left(1 - \lambda S_t^{\gamma}\right)\alpha}{b_1 + b_2 S_t^{\gamma}}\right]\sigma_c.$$

- How does this model performs?
- The following are some statistics of the market portfolio:

Basic Moments to Explain

Table I
Basic moments

Panel A: Summary statistics for the market portfolio

$E(R^M)$	vol(R^M)	r^f	vol(r^f)
7.71%	16.25%	1.44%	3.08%

Panel B: Predictability regressions

	Panel B-1: Sample 1948-2001				Panel B-2: Sample 1948-1995			
Horizon	4	8	12	16	4	8	12	16
$\ln\left(\frac{D}{P}\right)$	.13	.2	.26	.35	.28	.48	.63	.78
t−stat.	(2.13)	(1.65)	(1.34)	(1.29)	(4.04)	(4.00)	(4.49)	(5.41)
R^2	.09	.10	.11	.14	.19	.32	.43	.54

A Calibration

- A simple calibration of the economy (not much parameter search here) is as follows:

Table III
Model parameters used in the simulation

Panel A: Consumption and preference parameters

μ_c	σ_c	γ	ρ	$\gamma/\overline{S}$	$\min\{\gamma/S_t\}$	α	k
.02	.015	1.5	.072	48	27.75	77	.13

Model Implications in Simulations

Table IV
Basic moments in simulated data

Panel A: Summary statistics for the aggregate portfolio

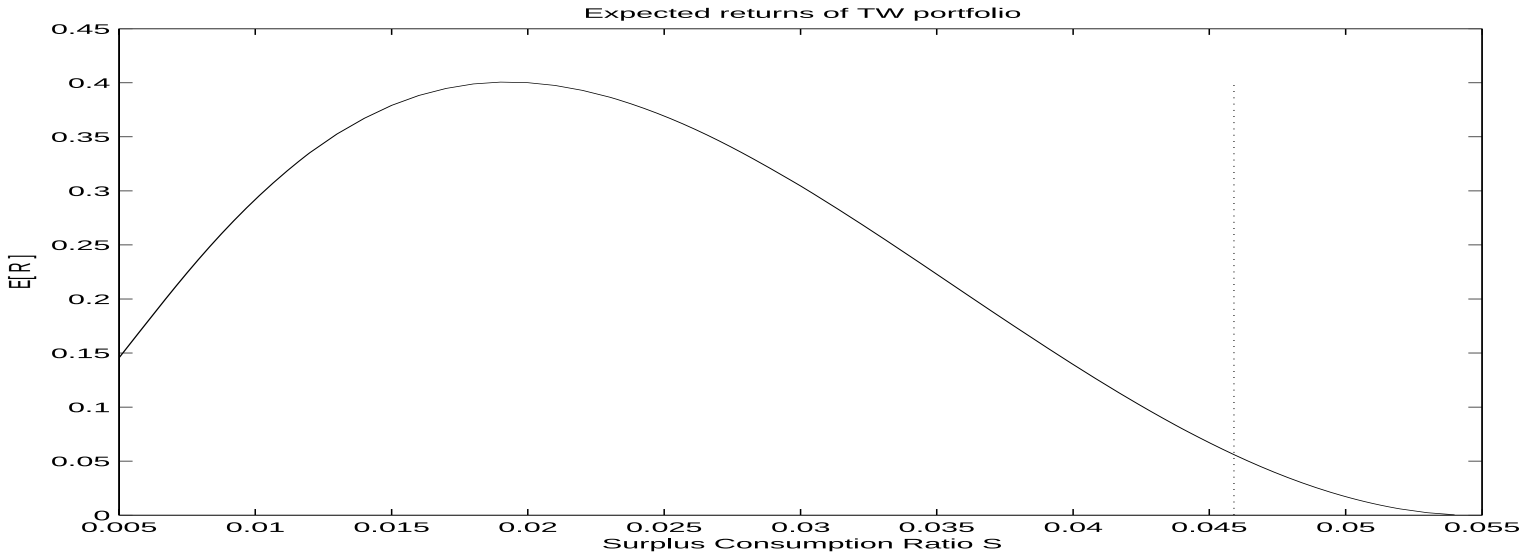
$E(R^M)$	vol(R^M)	r^f	vol(r^f)
9.96%	24.15%	.91%	5.41%

Panel B: Predictability regressions

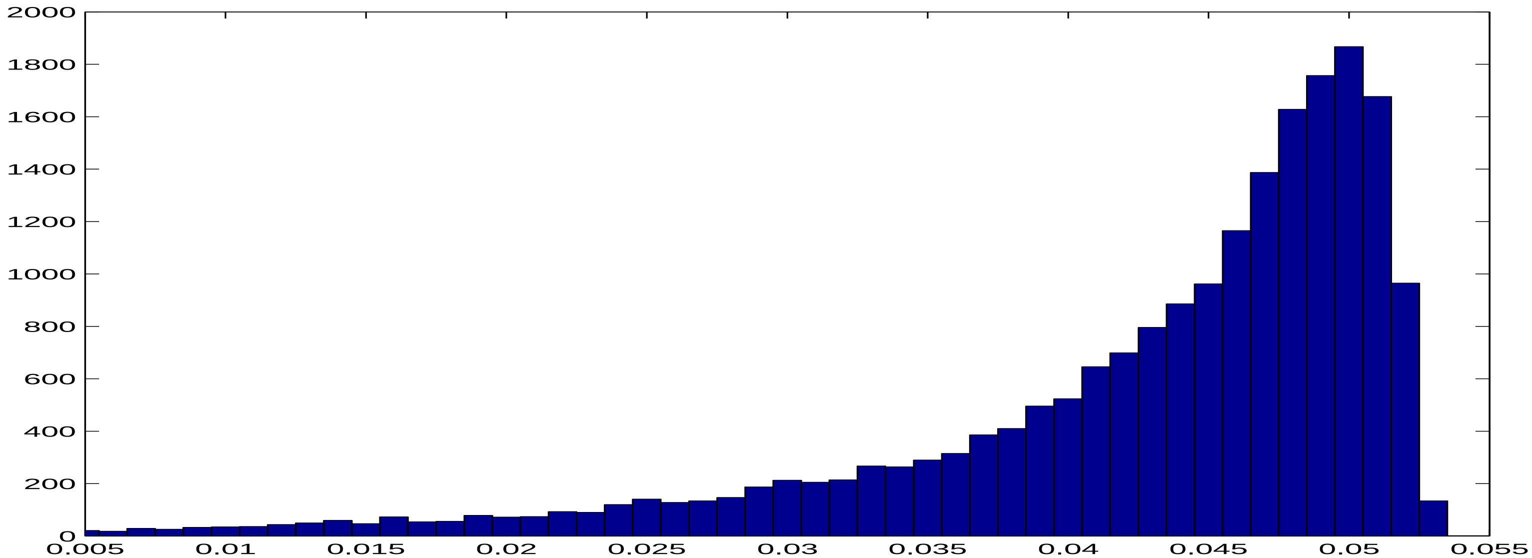
Horizon	4	8	12	16
$\ln\left(\frac{D}{P}\right)$	.73	.86	.88	.85
R^2	.25	.30	.29	.27

- The model does well, although the volatility of interest rates is a little too high
- The following figures shows the source of the effects

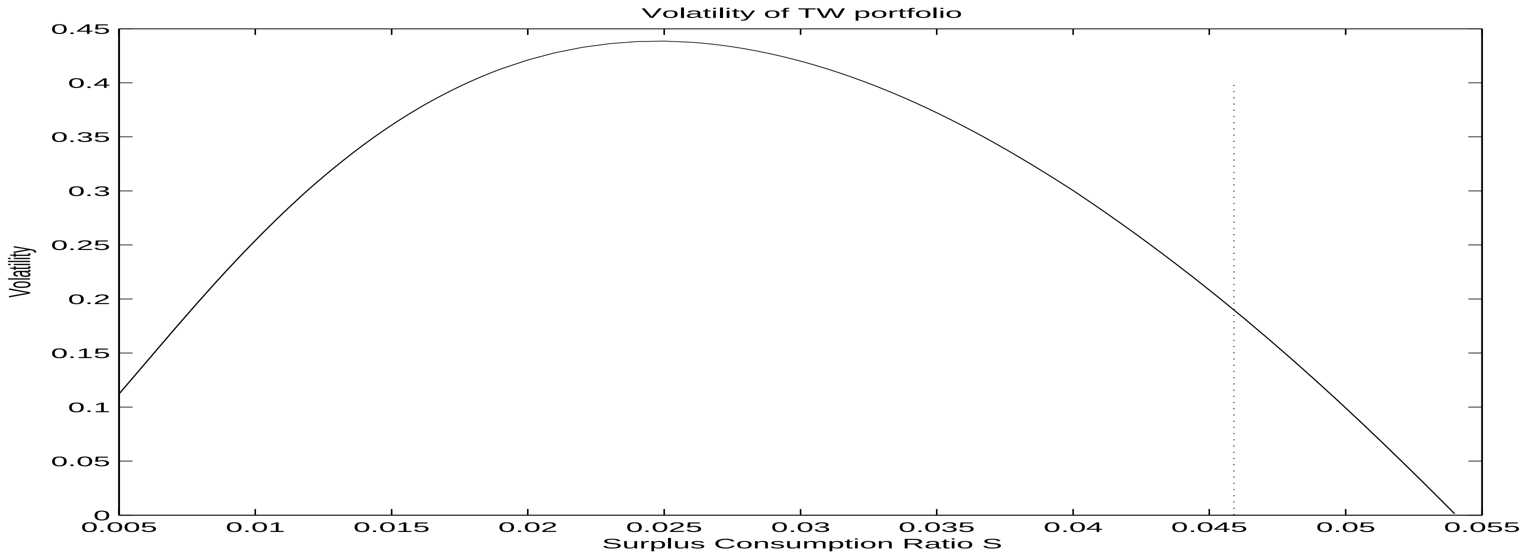
Expected Return



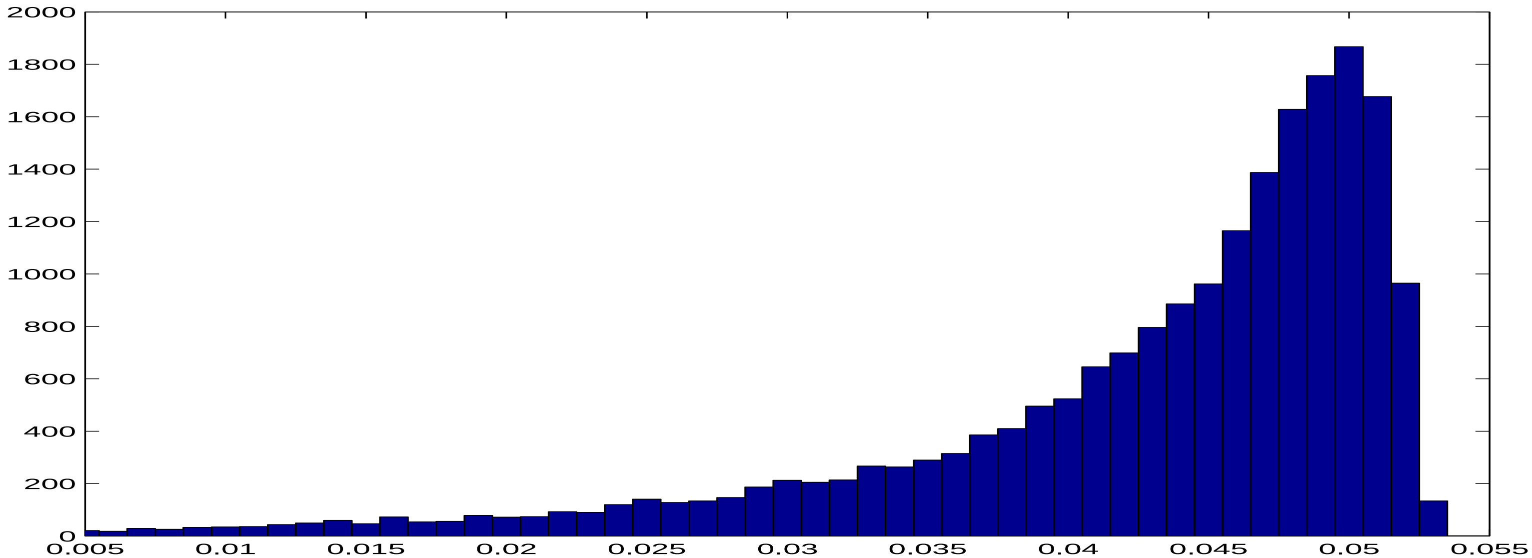
Distribution of S_t



Conditional Volatility

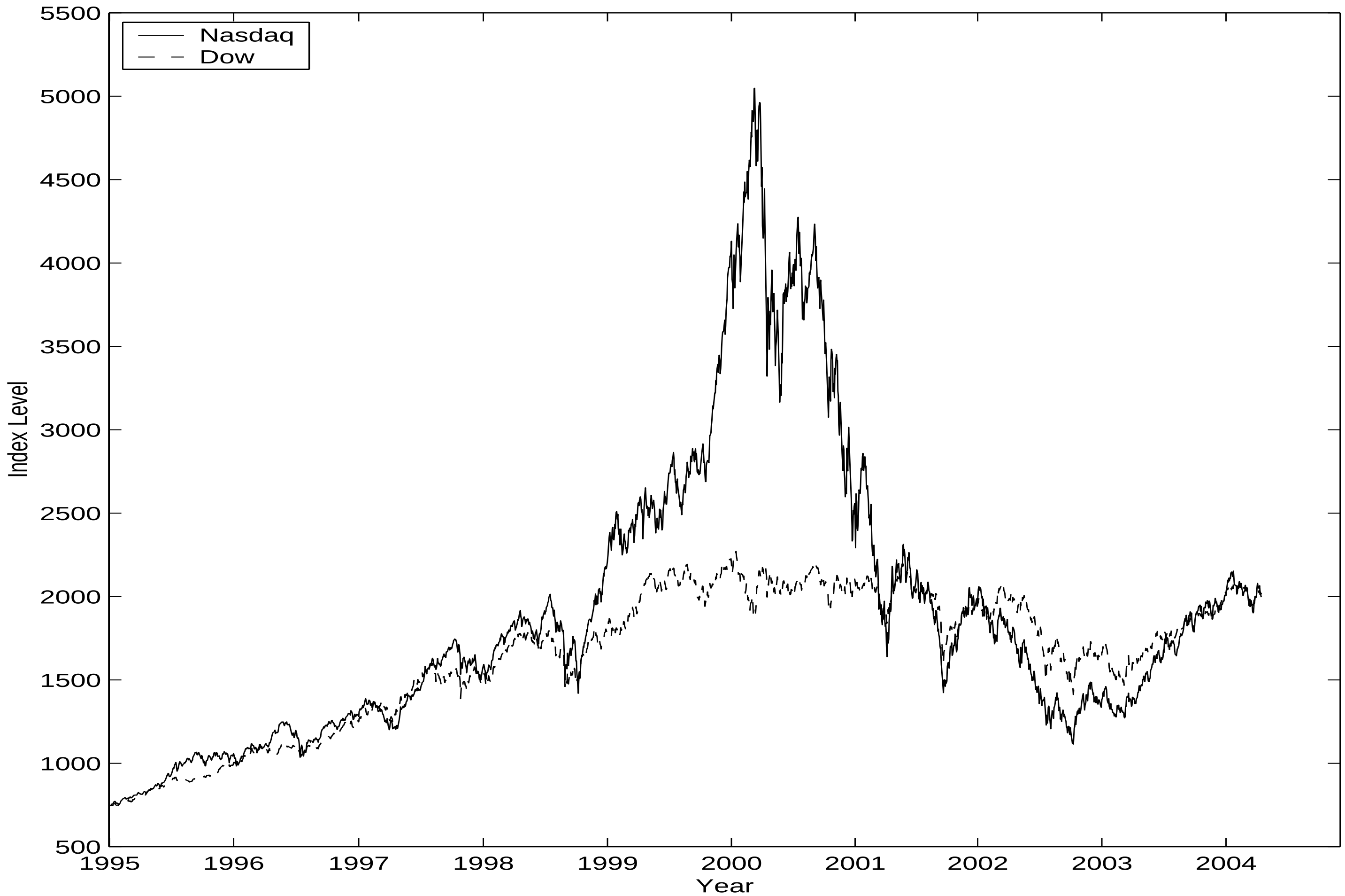


Distribution of S_t



Habit Preferences, Uncertainty and the 1990s "Bubble"

- Pastor and Veronesi (2006) use a similar setting with uncertainty about average profitability to rationalize the high valuations in the late 1990s



Why Was Uncertainty about Average Profitability High in the Late 1990s?

- Technological revolution; "new era"
- Stock price reaction to earnings surprises was stronger in 1996-1999 than in 1992-1995 (Ahmed, Schneible, and Stevens, 2003)
- Firms went public earlier in their life-cycles (Schultz and Zaman, 2001)
- Tech stock profitability was highly volatile
- Tech stock prices were highly volatile
- Anecdotal evidence

  "...the projections of revenue growth were, by and large, wild guesses."

  Investment Dealers Digest, 23 October 2000.

  "Internet firms' highly unpredictable growth rates make historical information less useful."

  TIAA-CREF Investment Forum, March 2001.

  "...being wrong isn't very costly, and being right has a high payoff... With Amazon, we believe the payoff for being right is high."

  Bill Miller, portfolio manager of the Legg Mason Value Trust, in Barron's, 15 Nov 1999.

Habit Preferences in PV

- PV use a different transformation of surplus consumption ratio

$$
\begin{aligned}
S_t &= e^{s_t} \\
s_t &= a_0 + a_1 y_t + a_2 y_t^2 \\
dy_t &= k_y \left(\overline{y} - y_t\right) dt + \sigma_y dW_{0,t}
\end{aligned}
$$

- Choosing a_i appropriately (in particular, $a_2 < 0$) $\Longrightarrow s_t < 0 \Longrightarrow S_t \in [0,1]$.
- The SDF is then given by

$$\pi_t = e^{-\eta t - \gamma(s_t + c_t)},$$

- with dynamics

$$\frac{d\pi_t}{\pi_t} = -r_t\, dt - \sigma_{\pi,t}\, dW_{0,t}$$

$$\sigma_{\pi,t} = \gamma \left(\sigma_\varepsilon + \left(a_1 + 2a_2 y_t\right) \sigma_y\right)$$

  – when $y_t \uparrow \Longrightarrow \sigma_{\pi,t} \downarrow \Longrightarrow$ equity premium $\downarrow$

Model: Profitability

- Firm profitability is measured as the accounting return on equity (ROE),

$$\rho_t = \frac{\text{Earnings}_t}{\text{Book Equity}_t} = \frac{Y_t}{B_t}$$

- Mean reversion in firm profitability:

$$d\rho_t^i \;=\; \phi^i(\underbrace{\overline{\rho}_t + \overline{\psi}_t^i}_{\overline{\rho}_t^i} - \rho_t^i)\, dt \;+\; \sigma_{i,0}\; \underbrace{dW_{0,t}}_{systematic} \;+\; \sigma_{i,i}\; \underbrace{dW_{i,t}}_{idiosyncratic}$$

  – $\overline{\rho}_t \ldots$ Average aggregate profitability

$$d\overline{\rho}_t = k_L\left(\overline{\rho}_L - \overline{\rho}_t\right) dt + \sigma_{L,0} dW_{0,t} + \sigma_{L,L} dW_{L,t}$$

  – $\overline{\psi}_t^i \ldots$ Average firm-specific excess profitability

$$d\overline{\psi}_t^i = -k_\psi \overline{\psi}_t^i dt$$

Model: Dividends

- Dividends are proportional to book equity:

$$D_t = c\ B_t, \qquad c \geq 0$$

- Clean surplus relation (assuming no new equity issues/withdrawals):

$$dB_t = (Y_t - D_t)\,dt = (\rho_t - c)\,B_t\ dt$$

Note: Since $\frac{dB_t}{B_t} = (\rho_t - c)\ \ dt$,

uncertainty about average $\rho_t =$ uncertainty about the average growth rate of B_t

Model: Market Value

- The abnormal earnings model of Ohlson (1990, 1995):

$$M_t = B_t + \text{present value of future abnormal earnings}$$

- Competition $\implies$ $M_T = B_T$ at some future time T
  - T is random, exponentially distributed with density $h(T; p)$
  - At any point in time, there is probability p that T arrives in the next instant

- Market value of equity:

$$M_t = E_t \left[\int_t^{\infty} \left(\int_t^T \frac{\pi_s}{\pi_t} D_s ds + \frac{\pi_T}{\pi_t} B_T \right) h(T; p) \; dT \right],$$

where π_t is given earlier

Valuation Formula

- **Proposition 1.** Suppose $\overline{\psi}_t^i$ is known.

$$\frac{M_t}{B_t} = G\left(\overline{\psi}_t^i; y_t, \overline{\rho}_t, \rho_t^i\right) = (c+p)\int_0^\infty Z\left(y_t, \overline{\rho}_t, \rho_t^i, \overline{\psi}_t^i, s\right) ds$$

- When $\overline{\psi}_t^i$ is unknown, the law of iterated expectations yields

$$\frac{M_t}{B_t} = E\left[G\left(\overline{\psi}_t^i; y_t, \overline{\rho}_t, \rho_t^i\right)\right] = \int G\left(\overline{\psi}_t^i; y_t, \overline{\rho}_t, \rho_t^i\right) f_t\left(\overline{\psi}_t^i\right) d\overline{\psi}_t^i$$

  Note: Since G is convex in $\overline{\psi}_t^i$, greater dispersion in $f_t\left(\overline{\psi}_t^i\right)$ increases M/B

- **Proposition 2.** Suppose that $\overline{\psi}_t^i$ is unknown, and that $f_t\left(\overline{\psi}_t^i\right) = N\left(\widehat{\psi}_t^i, \widehat{\sigma}_{i,t}^2\right)$.

$$\frac{M_t}{B_t} = (c+p)\int_0^\infty Z\left(y_t, \overline{\rho}_t, \rho_t^i, \widehat{\psi}_t^i, s\right) e^{\frac{1}{2}Q_4(s)^2\widehat{\sigma}_{i,t}^2}\, ds$$

- Note: M/B increases if

  (i) expected profitability increases ($\widehat{\psi}_t^i \uparrow$, $\overline{\rho}_t \uparrow$, $\rho_t^i \uparrow$)

  (ii) the discount rate decreases ($y_t \uparrow \Rightarrow$ equity premium $\downarrow$)

  (iii) uncertainty about $\overline{\psi}_t^i$ increases ($\widehat{\sigma}_{i,t} \uparrow$)

Calibration

- Two sectors:
  - "New economy" (Nasdaq): described above
  - "Old economy" (NYSE/Amex): pays dividends $D_t^O = c^O B_t^O$ forever

    Old economy's market value is $M_t^O = E_t\left[\int_t^\infty \frac{\pi_s}{\pi_t} D_s^O ds\right]$, we derive $M_t^O / B_t^O = \Phi\left(\overline{\rho}_t, y_t\right)$
- The profitability parameters are estimated from the data
- The SDF parameters are calibrated to match the old economy's average return, volatility, M/B, and the level of interest rate to their empirical counterparts

Table 1

Old Economy Profitability				New Economy Profitability			Individ. Firm Profitability		
k_L	$\overline{\rho}_L$	σ_{LL}	$\sigma_{L,0}$	ϕ^N	$\sigma_{0,N}$	$\sigma_{N,N}$	ϕ^i	$\sigma_{i,0}$	$\sigma_{i,i}$
0.3574	12.17%	1.47%	1.31%	0.3551	2.93%	4.88%	0.3891	6.65%	8.07%
Stochastic Discount Factor									
η	γ	k_y	$\overline{y}$	σ_y	a_0	a_1	a_2	μ_ε	σ_ε
0.0471	3.9474	0.0367	-0.08%	25.30%	-2.8780	0.3084	-0.0413	2%	1%
Means of Fitted Quantities				Std Deviations of Fitted Quantities					
$E[M/B]$	$E\left[\mu_{R,t}^{mkt}\right]$	$E\left[\sigma_{R,t}^{mkt}\right]$	$E[r_{f,t}]$	$\sigma[M/B]$	$\sigma\left[\mu_{R,t}^{mkt}\right]$	$\sigma\left[\sigma_{R,t}^{mkt}\right]$	$\sigma[r_{f,t}]$	c^O	k_ψ
1.77	5.06%	14.47%	6.25%	0.6477	1.72%	2.24%	1.55%	5.67%	0.0139

Table 2. Nasdaq's Valuation on March 10, 2000 Assuming Zero Uncertainty

$\rho_t^N = 9.96\%$ per year, $c = 1.35\%$ per year, $\mathsf{E}(T) = 20$ years.

Excess ROE	Equity Premium (% per year)							
$\hat{\psi}^N$ (% per year)	1	2	3	4	5	6	7	8
	Panel A: Model-implied M/B with zero uncertainty (Actual M/B: 8.55)							
0	3.33	3.02	2.63	2.23	1.84	1.47	1.12	0.76
1	4.15	3.70	3.17	2.64	2.14	1.68	1.25	0.83
2	5.27	4.62	3.89	3.19	2.53	1.95	1.41	0.90
3	6.83	5.89	4.87	3.92	3.05	2.29	1.62	1.00
4	9.06	7.68	6.23	4.92	3.75	2.74	1.88	1.11
5	12.28	10.22	8.15	6.31	4.71	3.36	2.23	1.26
6	17.02	13.92	10.90	8.28	6.04	4.19	2.69	1.45
7	24.09	19.38	14.91	11.12	7.93	5.36	3.32	1.69
	Panel B: Implied return volatility with zero uncertainty (Actual volatility: 41.5% in March 2000, 47% in 2000)							
0	18.09	20.17	21.76	22.93	23.76	24.18	24.10	23.04
1	18.69	20.93	22.65	23.92	24.83	25.31	25.22	24.05
2	19.31	21.71	23.57	24.97	25.97	26.52	26.46	25.18
3	19.93	22.50	24.52	26.05	27.18	27.83	27.81	26.45
4	20.54	23.30	25.47	27.16	28.44	29.21	29.27	27.85
5	21.14	24.07	26.42	28.27	29.72	30.66	30.85	29.42
6	21.71	24.82	27.34	29.37	31.01	32.15	32.52	31.15
7	22.25	25.53	28.23	30.44	32.28	33.65	34.27	33.05

Table 3. Nasdaq's Valuation on March 10, 2000 Assuming Uncertainty of 3% Per Year

$\rho_t^N = 9.96\%$ per year, $c = 1.35\%$ per year, $\mathsf{E}(T) = 20$ years.

Excess ROE	Equity Premium (% per year)							
$\hat{\psi}^N$ (% per year)	1	2	3	4	5	6	7	8
	Panel A: Model-implied M/B with 3% uncertainty (Actual M/B: 8.55)							
0	4.70	4.09	3.43	2.81	2.23	1.72	1.26	0.82
1	6.16	5.27	4.33	3.47	2.69	2.02	1.44	0.90
2	8.29	6.95	5.59	4.39	3.33	2.43	1.67	1.00
3	11.44	9.40	7.41	5.69	4.21	2.99	1.98	1.13
4	16.17	13.03	10.07	7.57	5.46	3.76	2.40	1.30
5	23.39	18.53	14.05	10.35	7.29	4.87	2.99	1.52
6	34.59	26.96	20.10	14.53	9.99	6.49	3.83	1.82
7	52.23	40.10	29.44	20.91	14.08	8.89	5.04	2.24
	Panel B: Implied return volatility with 3% uncertainty (Actual volatility: 41.5% in March 2000, 47% in 2000)							
0	33.66	33.93	33.97	33.76	33.22	32.25	30.62	27.60
1	35.63	35.96	36.06	35.89	35.37	34.36	32.60	29.23
2	37.59	38.02	38.21	38.12	37.66	36.66	34.81	31.11
3	39.51	40.05	40.37	40.41	40.05	39.13	37.26	33.25
4	41.33	42.03	42.50	42.70	42.51	41.73	39.93	35.70
5	43.05	43.91	44.56	44.94	44.96	44.40	42.77	38.46
6	44.65	45.67	46.50	47.09	47.35	47.07	45.73	41.52
7	46.11	47.29	48.31	49.10	49.63	49.67	48.72	44.85

Table 4. Matching Nasdaq's Valuation on March 10, 2000

$\rho_t^N = 9.96\%$ per year, $c = 1.35\%$ per year, $\mathrm{E}(T) = 20$ years.

Excess ROE	Equity Premium (% per year)							
$\hat{\psi}^N$ (% per year)	1	2	3	4	5	6	7	8
	Panel A. Uncertainty needed to match the observed M/B							
0	4.39	4.71	5.06	5.43	5.81	6.22	6.67	7.27
1	3.81	4.17	4.59	5.01	5.44	5.89	6.38	7.03
2	3.08	3.54	4.04	4.53	5.03	5.54	6.08	6.77
3	2.08	2.73	3.38	3.98	4.57	5.15	5.75	6.50
4	0.00	1.45	2.51	3.32	4.04	4.71	5.39	6.22
5	0.00	0.00	0.97	2.43	3.40	4.22	5.00	5.91
6	0.00	0.00	0.00	0.78	2.56	3.63	4.56	5.58
7	0.00	0.00	0.00	0.00	1.18	2.90	4.06	5.23
	Panel B. Return volatility under implied uncertainty (Actual volatility: 41.5% in March 2000, 47% in 2000)							
0	64.69	73.70	85.81	100.56	119.11	142.51	173.80	223.37
1	51.35	60.15	71.80	85.98	103.93	126.70	157.49	206.85
2	38.94	47.54	58.69	72.23	89.41	111.45	141.54	190.50
3	27.79	36.12	46.66	59.43	75.73	96.84	126.12	174.41
4	20.54	26.53	36.07	47.81	63.03	83.03	111.22	158.63
5	21.14	24.07	27.70	37.78	51.53	70.16	96.98	143.20
6	21.71	24.82	27.34	30.14	41.66	58.44	83.59	128.22
7	22.25	25.53	28.23	30.44	34.09	48.24	71.18	113.79

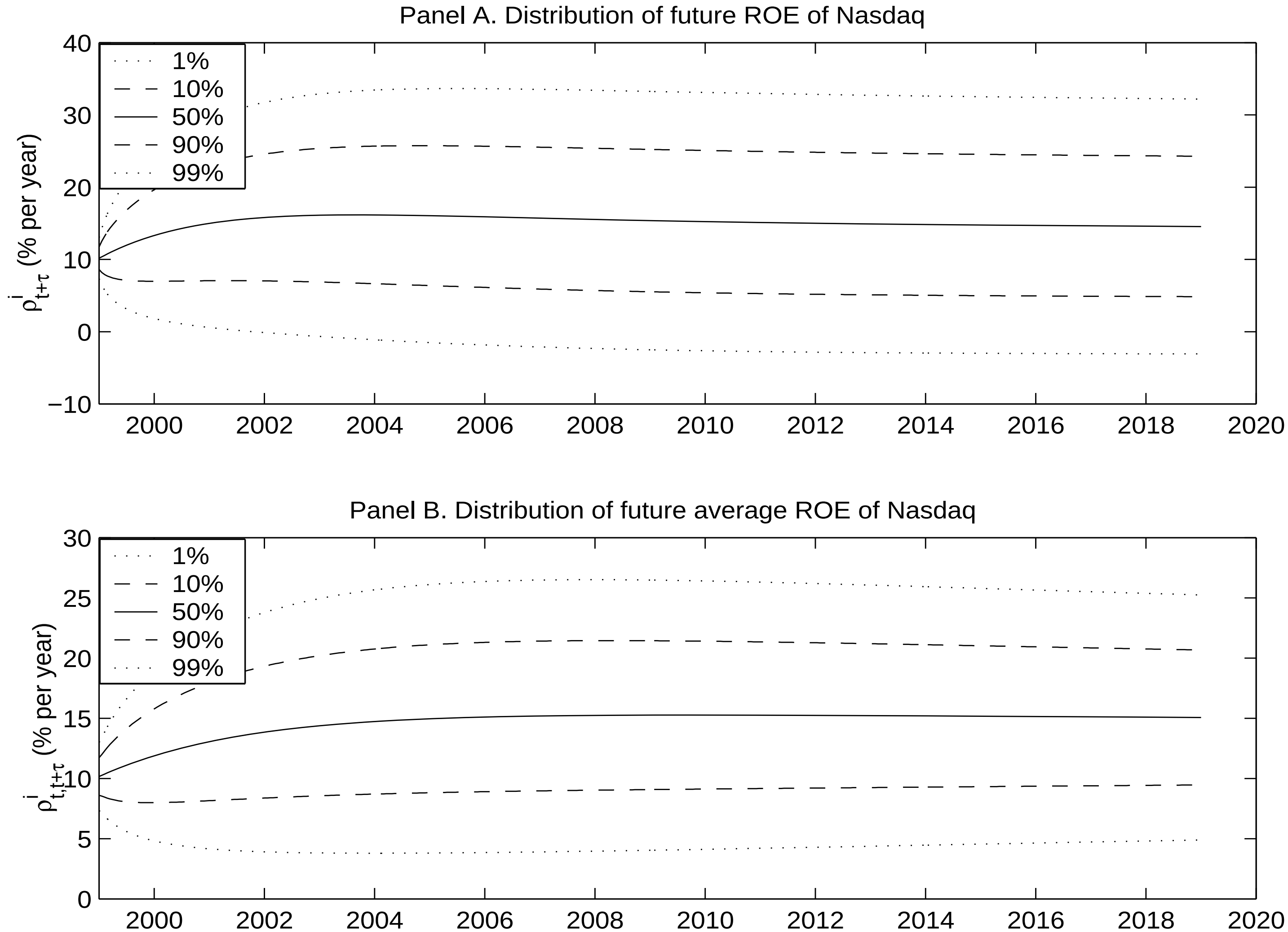
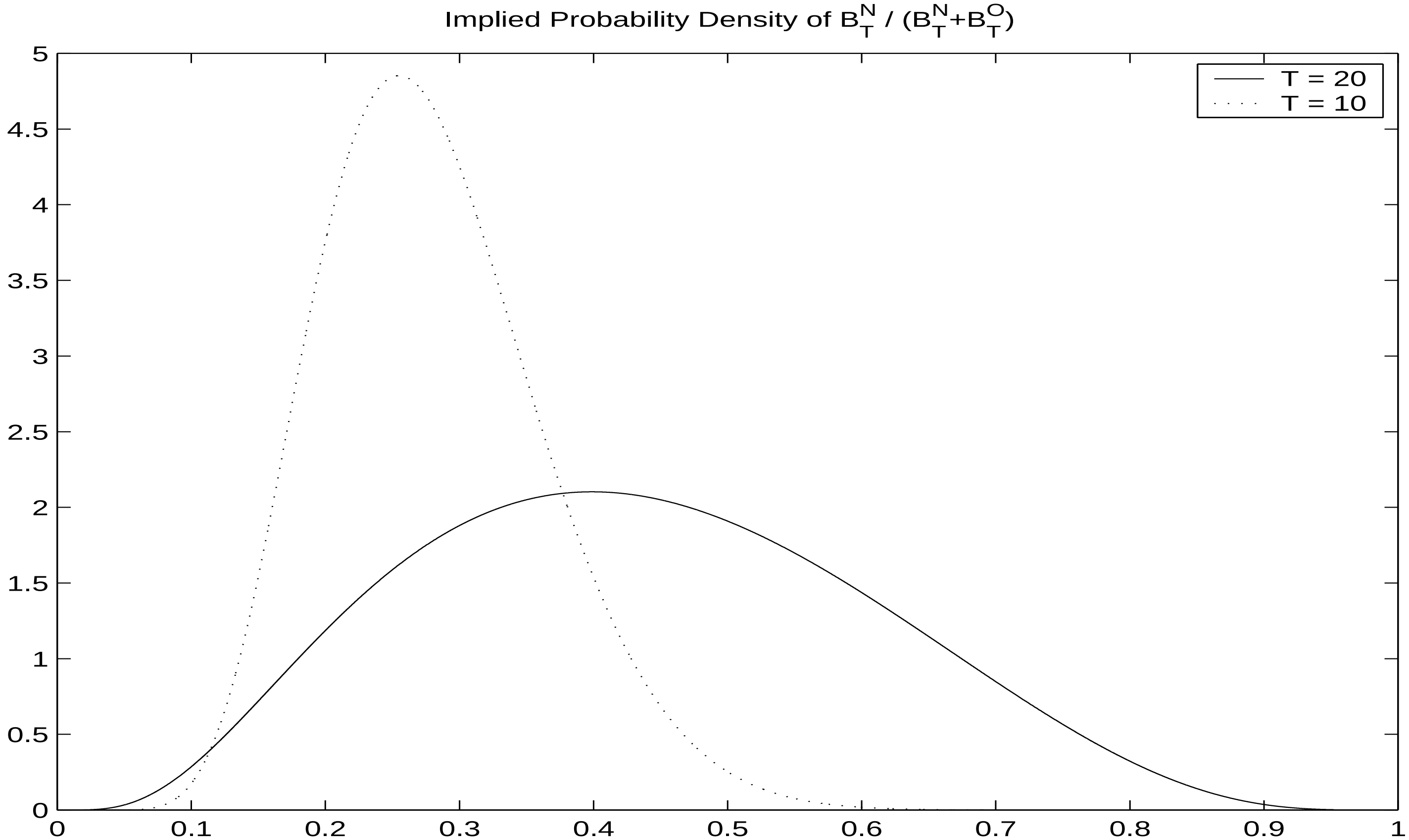


Figure 1. Model-predicted distributions of future profitability and average future profitability for Nasdaq.

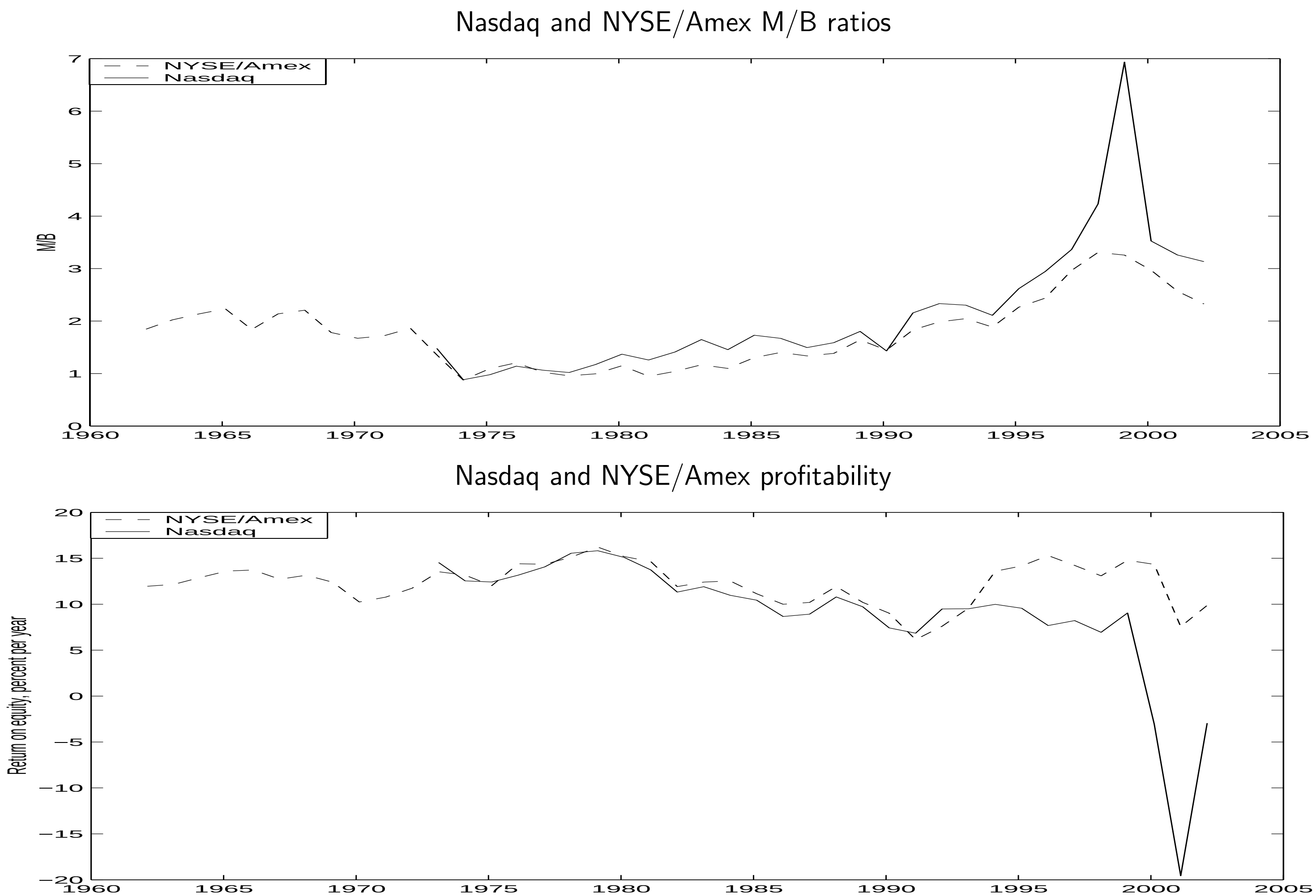


Model-predicted distribution of the future ratio of Nasdaq book value to NYSE/Amex/Nasdaq book value.

	Percentile								
T	1	5	10	25	50	75	90	95	99
10	0.12	0.16	0.18	0.22	0.27	0.33	0.39	0.43	0.50
20	0.11	0.17	0.22	0.31	0.43	0.56	0.67	0.73	0.82

Why Did the "Bubble" Burst?

- There is little doubt of what caused tech stock prices to drop in 2000.
  - Nasdaq's profitability plummeted in 2000.



Why Did the “Bubble” Burst?

- Is this large drop consistent with our model?
  - Yes
    - A high uncertainty about long term profitability implies large revisions when there are large unexpected events.
    - Our model implies a similar drop in M/B in 2000, and an even larger drop in 2001.

- Return volatility did not move much after March 2000.
  - This is also consistent with our model: Uncertainty remained high even after March 2000.

Technological Revolutions and Asset Prices

- The 1990s tech revolution and tech "bubble" was just the last example of a pattern repeated several times in history.

"Technological revolutions and financial bubbles seem to go hand in hand."

"Every previous technological revolution has created a speculative bubble...
With each wave of technology, share prices soared and later fell..."

(The Economist, September 21, 2000)

- Stock prices tend to exhibit bubble-like patterns during technological revolutions
  - Prices rise and then fall, especially for innovative firms
  - Return volatility is high, especially for innovative firms
- Examples:
  - the early 1980s (biotechnology, PC)
  - the early 1960s (electronics)
  - the 1920s (electricity, automobiles)
  - the early 1900s (radio)

Technological Uncertainty and Increase in Risk

- Uncertainty and learning also imply one additional reason why prices should decline during a technological revolution.
  - *Technological Revolutions imply an Increase in Risk*

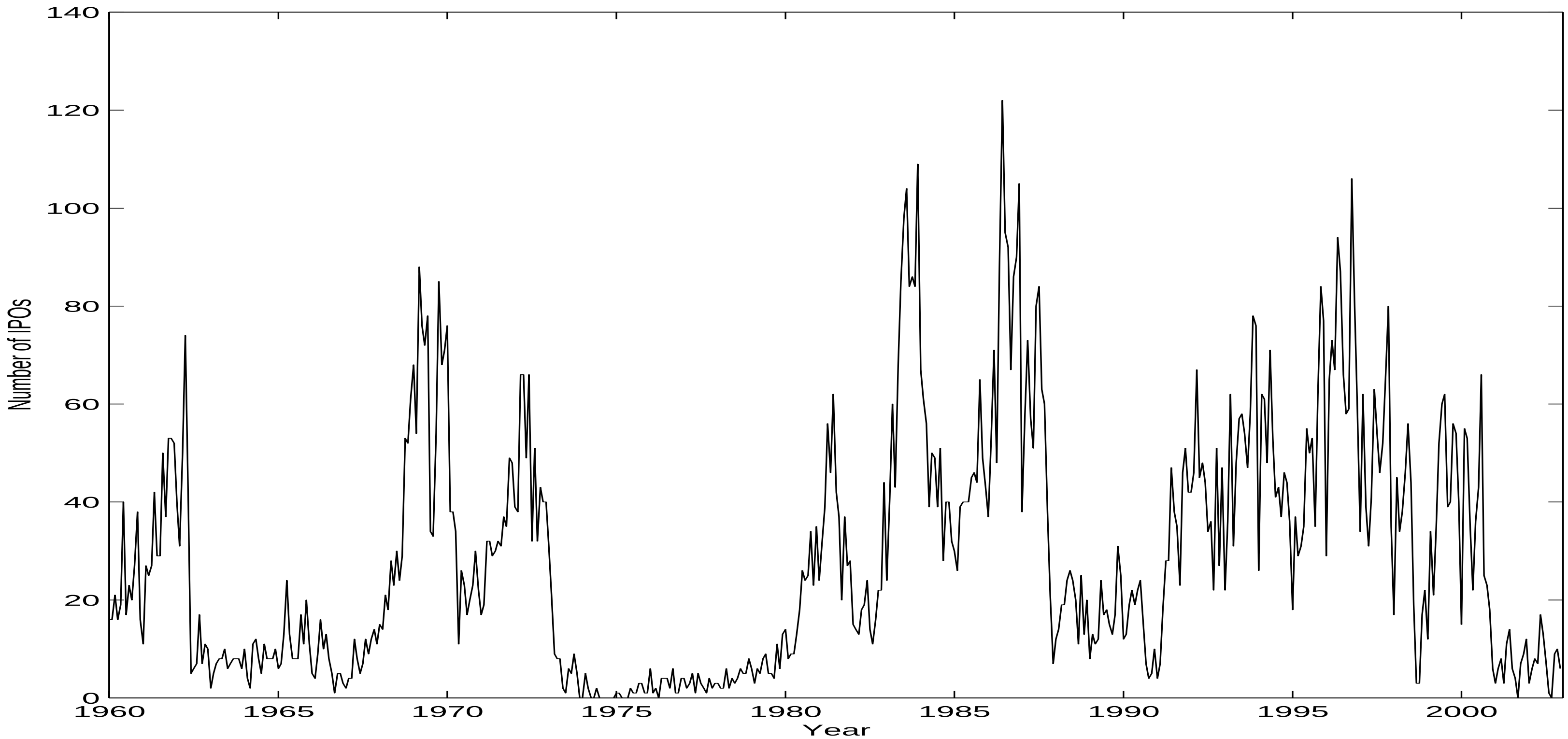
    (See Pastor and Veronesi, "Technological Revolutions and Stock Prices," NBER WP 2005)

- Why?
  - Productivity of new technologies is uncertain
    - $\Longrightarrow$ High volatility
  - Initially, this uncertainty is mainly **idiosyncratic** as new technologies are developed on a small case
    - $\Longrightarrow$ prices up (e.g. PV 2003)
  - If technology was eventually adopted (as in a *Tech Revolution*), the uncertainty gradually changes from idiosyncratic to **systematic**.
    - $\Longrightarrow$ discount rate up and prices down.
  - This model implies all of the stylized facts discussed earlier.
- This theory was recently validated empirically by Barath and Viswanathan (2006).

Habit, Uncertainty and IPO Waves

Why does IPO volume fluctuate?

How is IPO volume related to stock prices?



Rational IPO Waves

- Pastor and Veronesi (2005, JF) develop a rational symmetric-information model of optimal IPO timing in an environment with time-varying market conditions
- Market conditions vary along three dimensions:
  - Time-varying expected market return
  - Time-varying expected aggregate profitability
  - Time-varying prior uncertainty about average excess profitability
- PV find, theoretically and empirically, that IPO volume is high after
  - Expected market return $\downarrow$
  - Expected aggregate profitability $\uparrow$
  - Prior uncertainty $\uparrow$

Empirical Predictions (1)

- PV's model is rich in testable predictions:
  1. IPO waves caused by declines in expected market return should be
     - preceded by high market returns
     - followed by low market returns
  2. IPO waves caused by increases in expected aggregate profitability should be
     - preceded by high market returns
     - followed by high aggregate profitability
  3. IPO waves caused by increases in prior uncertainty should be
     - preceded by high disparity between new firms and old firms in terms of their valuations and volatilities

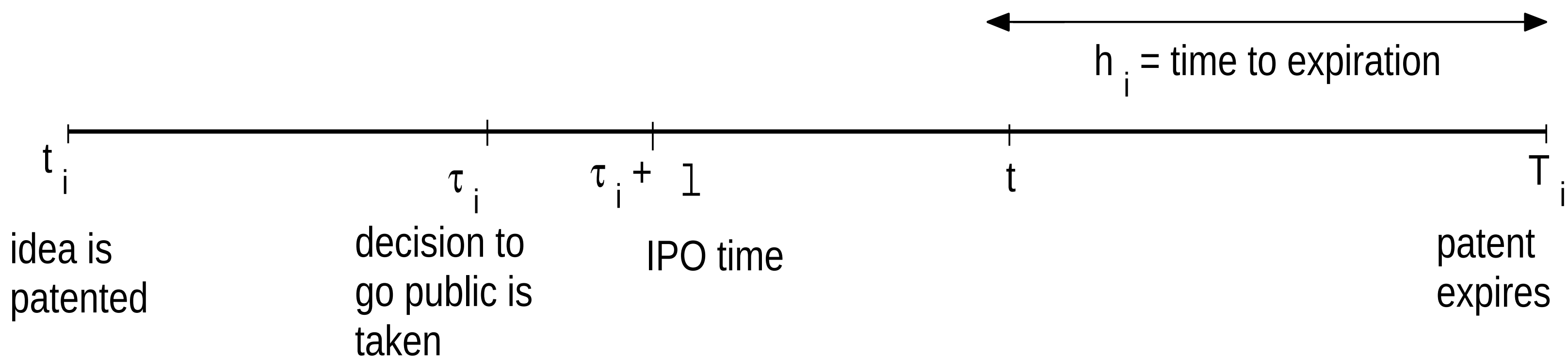
- PV test the model's implications using data between 1960 and 2002
- Empirical results lend considerable support to all three channels (discount rate, cash flow, and uncertainty).

Empirical Predictions (2)

- The model also predicts that
  1. IPO volume is related more to recent changes in prices than to the level of prices
     - IPOs take place especially after market conditions improve (and prices go up); when prices are high, many private firms have already gone public
     - The level of prices matters as well, but much less than changes in prices
  2. IPO valuations are especially high
     - Low discount rate and high expected profitability
     - High prior uncertainty (Pástor and Veronesi, 2003)
  3. After IPO, M/B is predicted to fall, on average
     - Uncertainty declines due to learning
     - Mean reversion in expected return and profitability
- These predictions are also confirmed empirically

Inventors and Investors

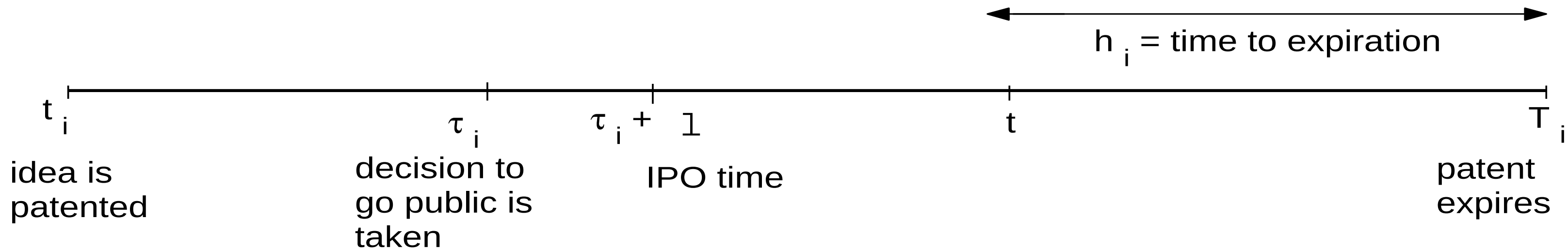
- Two types of agents
  1. Inve*n*tors: Invent patentable ideas, but lack capital
  2. Inve*s*tors: Cannot invent ideas, but have capital
- Both types of agents are otherwise identical
  - Same information
  - Same preferences (both maximize expected habit utility from consumption)
  - Same amount of wealth (inventors: human capital; investors: financial capital)
- Timing:



Time Varying Market Conditions

- Aggregate average profitability is time varying.
  - Business cycle
- All agents are identical and endowed with habit persistence preferences.
  - $\Longrightarrow$ Time varying aggregate expected returns
- Agents uncertainty about firm-specific average profitability is also time varying
  - E.g. Tech revolutions

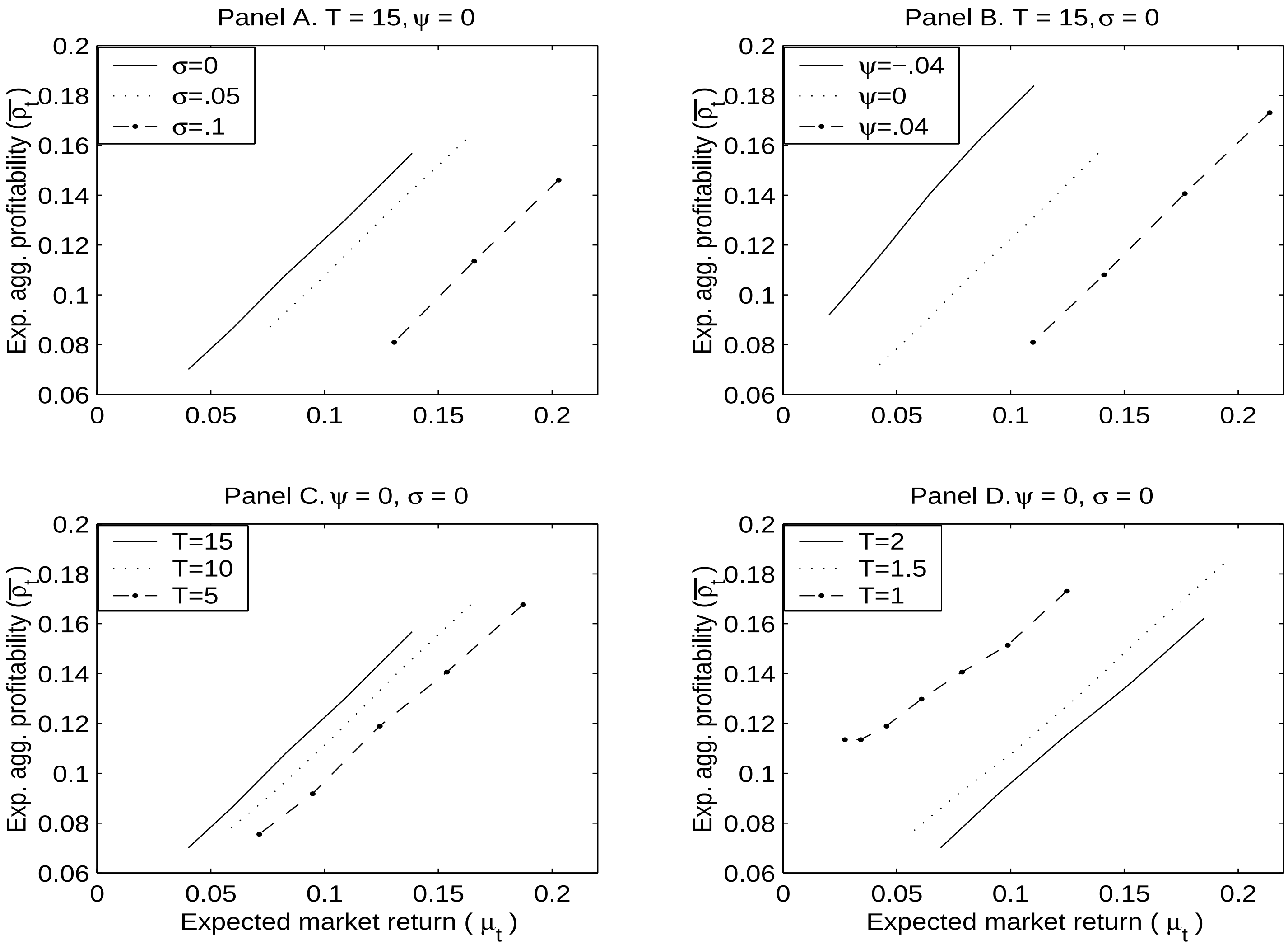
Optimal IPO Timing



- At time τ, IPO is filed, at $\tau + \ell$, IPO takes place ($\ell = 3$ months, Lowry and Schwert, 2002)
  1. $M^i_{\tau+\ell}$, fair market value of the firm computed earlier, is raised
  2. $f = 7\%$ underwriting fee is paid
  3. Initial investment B^{t_i} is made, production begins
  4. Equity issued in the IPO keeps the markets dynamically complete
- Inventor essentially owns an American option that can be exercised by going public
- Inventor chooses IPO time to maximize the value of his patent:

$$V\left(\overline{\rho}_t, y_t, \widehat{\sigma}_t, h_i\right) = \max_{\tau} E_t \left\{ \frac{\pi_{\tau+\ell}}{\pi_t} \underbrace{\left(M^i_{\tau+\ell}\left(1-f\right) - B^{t_i}\right)}_{inventor's\ payoff} \right\}$$

- The optimal stopping time problem is solved numerically



Optimal IPO Timing.

Simulating IPO Waves

- Assume one idea is born every month
  - note that IPO waves arise even when the pace of innovation is constant
- Simulate 10,000 years of data
- Use parameters calibrated to the old economy, as in "bubble"

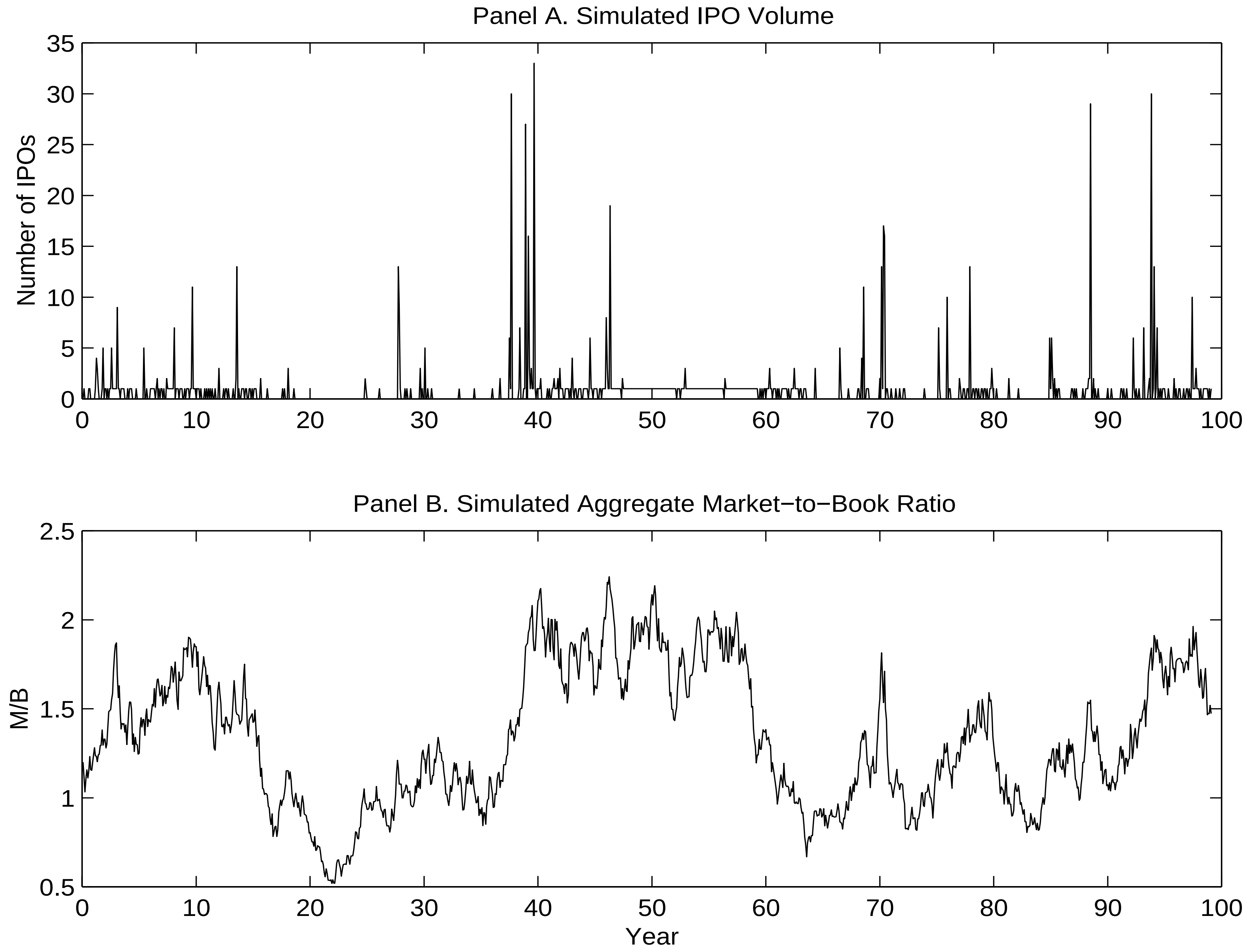

Panel A. Simulated IPO Volume
Number of IPOs
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60
70
80
90
100
Panel B. Simulated Aggregate Market−to−Book Ratio
M/B
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
70
80
90
100
Year

Table 3

Simulation Evidence: Regressions of IPO Volume on Selected Variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Intercept	2.25	2.21	2.22	2.03	2.22	2.23	0.69	2.22	2.22
ΔER-2	-0.24								
ΔER-1	-0.65								
$\Delta\bar{\rho}$-2		0.05							
$\Delta\bar{\rho}$-1		0.46							
$\Delta\hat{\sigma}$-2			0.08						
$\Delta\hat{\sigma}$-1			0.34						
MKT-2				4.30					
MKT-1				9.92					
MKT				-1.50					
MKT+1				-1.78					
MKT+2				-1.53					
ΔMVOL-2					-0.15				
ΔMVOL-1					-0.98				
ΔRF-2						-0.25			
ΔRF-1						-0.87			
M/B-1							0.93		
ΔNEWMB-2								0.07	
ΔNEWMB-1								6.54	
ΔNEWVOL-2									0.00
ΔNEWVOL-1									0.03
IPO(t-1)	0.19	0.20	0.20	0.18	0.20	0.20	0.16	0.20	0.20
T	40000	40000	40000	40000	40000	40000	40000	40000	40000
R^2	0.11	0.04	0.05	0.12	0.08	0.10	0.07	0.08	0.04

Proxies

- Two proxies for prior uncertainty:

$$\begin{aligned} NEWVOL_t &= \sigma_{R,t}^{ipo} - \sigma_{R,t}^{m}, \\ NEWMB_t &= \log\left(M_t^{ipo}/B_t^{ipo}\right) - \log\left(M_t^{m}/B_t^{m}\right) \end{aligned}$$

  - in the simulation, both proxies are highly correlated with prior uncertainty but not with the other two dimensions of market conditions

- Two proxies for expected market return:

$$\begin{aligned} MVOL_t &= \sigma_{R,t}^{m}, \\ \text{Realized returns} &\ \ldots\ R_t^{m} \end{aligned}$$

  - in the simulation, both proxies are highly correlated with expected market return but not with the other two dimensions of market conditions

Empirical Evidence

- Data
  - IPOs:
    - Jay Ritter's data: January 1960 through December 2002
    - Number of IPOs is deflated by the number of public firms at previous month-end
  - MKT and MVOL from CRSP
  - Aggregate M/B and aggregate profitability (ROE) from COMPUSTAT
  - Additional proxy for expected profitability:
    - I/B/E/S average forecast of long-term earnings growth
  - Risk free rate = yield on a one-month T-bill
- Tables 5 and 6: Empirical counterparts to Tables 2 and 3

Table 6a, Empirical Evidence: Regressions of IPO Volume on Selected Variables

	(1)	(2)	(3)	(4)	(5)
Intercept	0.23	0.31	0.33	0.33	0.28
	(3.03)	(4.48)	(4.76)	(2.51)	(2.02)
MKT-2	1.67				1.68
	(3.25)				(3.23)
MKT-1	2.09				2.11
	(3.34)				(3.27)
MKT	2.06				2.03
	(4.51)				(4.50)
MKT+1	-0.95				-0.98
	(-2.23)				(-2.25)
MKT+2	-0.49				-0.52
	(-0.74)				(-0.77)
ΔMVOL-2		-0.31			
		(-1.91)			
ΔMVOL-1		-0.63			
		(-3.59)			
ΔMVOL		-0.60			
		(-4.41)			
ΔRF-2			1.10		
			(3.10)		
ΔRF-1			0.28		
			(1.21)		
ΔRF			0.91		
			(2.53)		
M/B-1				0.01	-0.03
				(0.12)	(-0.44)
IPO(t-1)	0.84	0.87	0.84	0.84	0.84
	(23.09)	(21.47)	(20.37)	(19.21)	(22.75)
Q1 Dummy	-0.48	-0.42	-0.38	-0.42	-0.43
	(-4.92)	(-4.52)	(-4.04)	(-4.91)	(-4.28)
T	169	159	171	169	157
R^2	0.78	0.75	0.73	0.72	0.79

Table 6b, Empirical Evidence: Regressions of IPO Volume on Selected Variables

	(6)	(7)	(8)	(9)	(10)
Intercept	0.34	0.57	0.31	0.37	0.37
	(3.92)	(5.04)	(4.33)	(4.67)	(3.77)
ΔROE	0.90				0.19
	(2.50)				(0.46)
ΔROE+1	0.55				0.31
	(1.43)				(0.76)
ΔROE+2	0.64				1.00
	(1.90)				(2.40)
ΔIBES-2		-0.16			
		(-0.87)			
ΔIBES-1		-0.43			
		(-1.37)			
ΔIBES		0.78			
		(5.07)			
ΔNEWMB-2			0.46		0.48
			(2.35)		(2.28)
ΔNEWMB-1			0.52		0.62
			(3.18)		(2.78)
ΔNEWMB			0.11		-0.11
			(0.59)		(-0.49)
ΔNEWVOL-2				0.12	0.12
				(2.23)	(2.87)
ΔNEWVOL-1				0.03	-0.00
				(0.57)	(-0.09)
ΔNEWVOL				0.01	-0.04
				(0.19)	(-0.94)
IPO(t-1)	0.84	0.79	0.87	0.84	0.86
	(18.30)	(11.16)	(19.79)	(18.75)	(16.56)
Q1 Dummy	-0.26	-0.67	-0.51	-0.43	-0.46
	(-2.22)	(-4.59)	(-5.40)	(-4.42)	(-3.26)
T	142	79	136	144	105
R^2	0.72	0.70	0.76	0.71	0.77

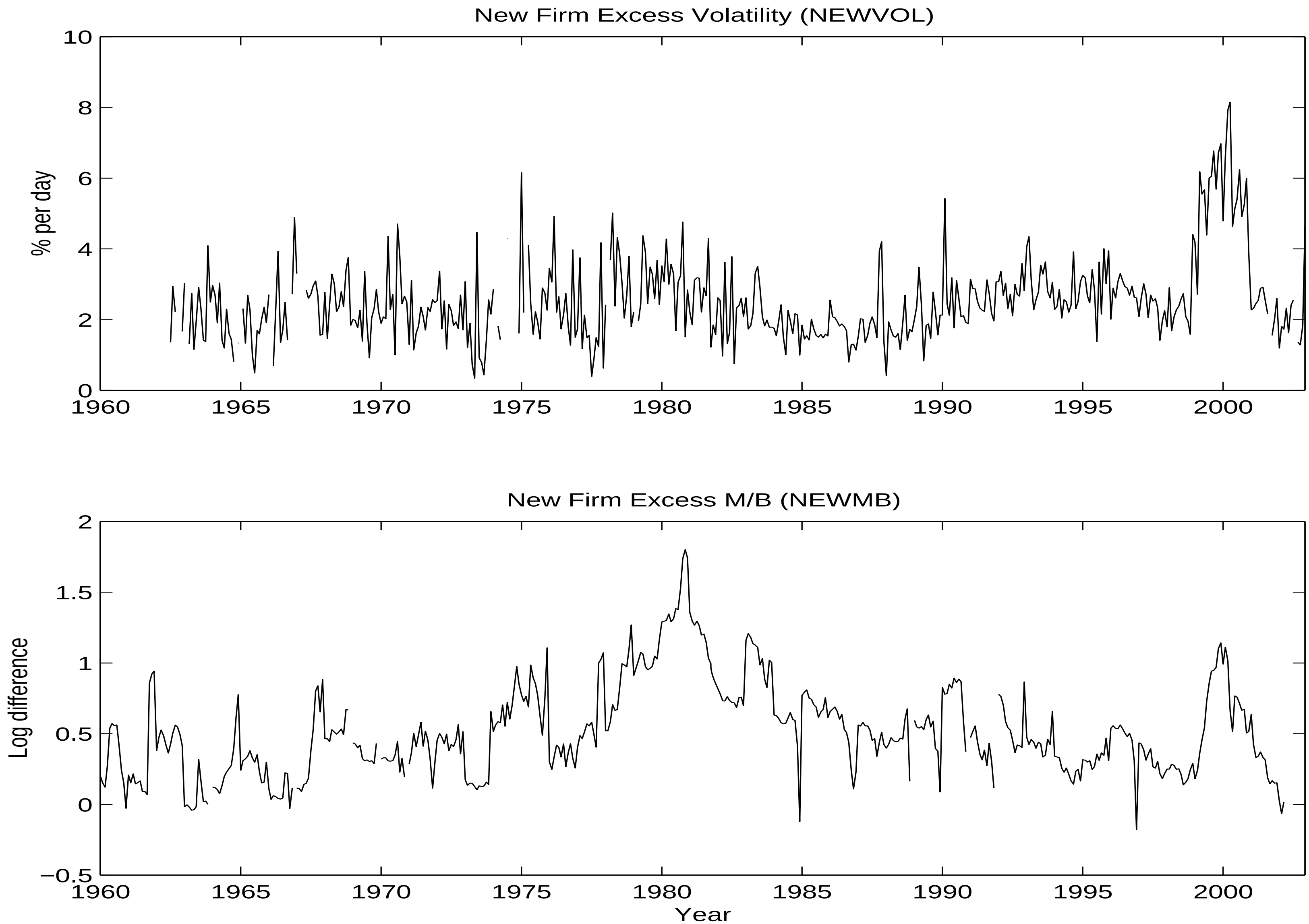


Figure 7. Monthly time series of proxies for prior uncertainty.

Conclusions

- Habit preferences + time varying uncertainty is able to capture many features of the data.
  1. Variation in conditional moments of stock returns.
  2. Predictability of aggregate stock returns
  3. A low and stable risk free rate
  4. Rationalize the high valuation in the late 1990s
  5. Explain why IPO volume is time varying
     - Generate many predictions that are consistent with the data
- Wachter (2004) and Buraschi and Jiltsov (2006) apply habit preferences to term structure models.
- As we will see, however, there are some features of habit persistence preferences that are at odds with other facts.