Repeated Signaling and Firm Dynamics

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The Agenda

- We have *numerous* dynamic structural models of trade-off theory.
- Limited set of dynamic moral hazard models: Bernanke and Gertler (1989); Clementi and Hopenhayn (2006); DeMarzo and Fishman (2007); and Biais et al. (2007).
- Calibrated model of moral hazard: Carlstrom and Fuerst (1997).

The Agenda Continued

- Ross (2005): "The introduction of the issues raised by the presence of asymmetric information in the determination of capital structure and the integration of these issues into the intertemporal neoclassical model are a major challenge."

- Gomes (2001): "Ideally we would prefer to model financial intermediation endogenously. This approach, however, would demand a far more complex model..."

- Baker & Wurgler (2002): "In practice, equity market timing appears to be an important aspect of real corporate financial policies."

The basic intuition of model

- Adverse selection most severe when net worth low.
- Shadow value of internal funds high when net worth low.
- Risk-neutral insider becomes pseudo-risk-averse.
- In LCSE, firm with negative info is insured (equity+financial slack).
- In LCSE, firm signals positive info with high debt. Default costs induce under-investment.
- Net worth low $\Rightarrow$ COSTLY separation $\Rightarrow$ pooling possible.

Assumption 3 (Shocks)

- Markovian private shock $\theta_t \in \{\theta_L, \theta_H\}$ with $0 < \theta_L < \theta_H$.
- $p(\theta_i|\theta_j)$=probability of θ_i conditional on lagged type θ_j.
- Public shock ε_t is iid with $\underline{\varepsilon} > 0$.
- Public shock ε_t has density $f : [\underline{\varepsilon}, \infty) \to [0, 1]$ which is continuously differentiable.

Solving for LCSE

PROGRAM L

$$\Gamma_L^S(w) \equiv \max_{a \in \mathcal{A}} \quad d_L + (1 - s_L)\Omega(b_L, k_L, \theta_L)$$

$$s.t.$$

$$BC_L : d_L + k_L - w \leq \rho(b_L, k_L, \theta_L) + s_L\Omega(b_L, k_L, \theta_L)$$

$$\Rightarrow a_L^S(w) \equiv (b_L^S, d_L^S, k_L^S, s_L^S)(w)$$

Solving for LCSE (continued)

PROGRAM H

$$\Gamma_H^S(w) \equiv \max_{a \in \mathcal{A}} \quad d_H + (1 - s_H)\Omega(b_H, k_H, \theta_H)$$

$s.t.$

$$BC_H : d_H + k_H - w \leq \rho(b_H, k_H, \theta_H) + s_H\Omega(b_H, k_H, \theta_H)$$

$$IC : d_L^S + (1 - s_L^S)\Omega(b_L^S, k_L^S, \theta_L) \geq d_H + (1 - s_H)\Omega(b_H, k_H, \theta_L)$$

$$\Rightarrow a_H^S(w) \equiv (b_H^S, d_H^S, k_H^S, s_H^S)(w)$$

Proposition 2

Let (a_L^S, a_H^S) *be least-cost separating contracts with respect to* (V_L^S, V_H^S) *where*

$$V_j^S(w) \equiv \sum_{i \in \{L,H\}} p(\theta_i|\theta_j)\Gamma_i^S(w)$$

and

$$\underline{w} \equiv -\max_{b,k} \quad \rho(b,k,\theta_L) + \Omega(b,k,\theta_L) - k.$$

Then $(\underline{w}, \underline{w}, a_L^S, a_H^S, V_L^S, V_H^S)$ *is a recursive perfect Bayesian equilibrium.*

Proof: $\Gamma_L^S(\underline{w}) = 0 \Rightarrow \Gamma_H^S(\underline{w}) = 0 \Rightarrow V_L^S(\underline{w}) = V_H^S(\underline{w}) = 0.$

Solution to program L

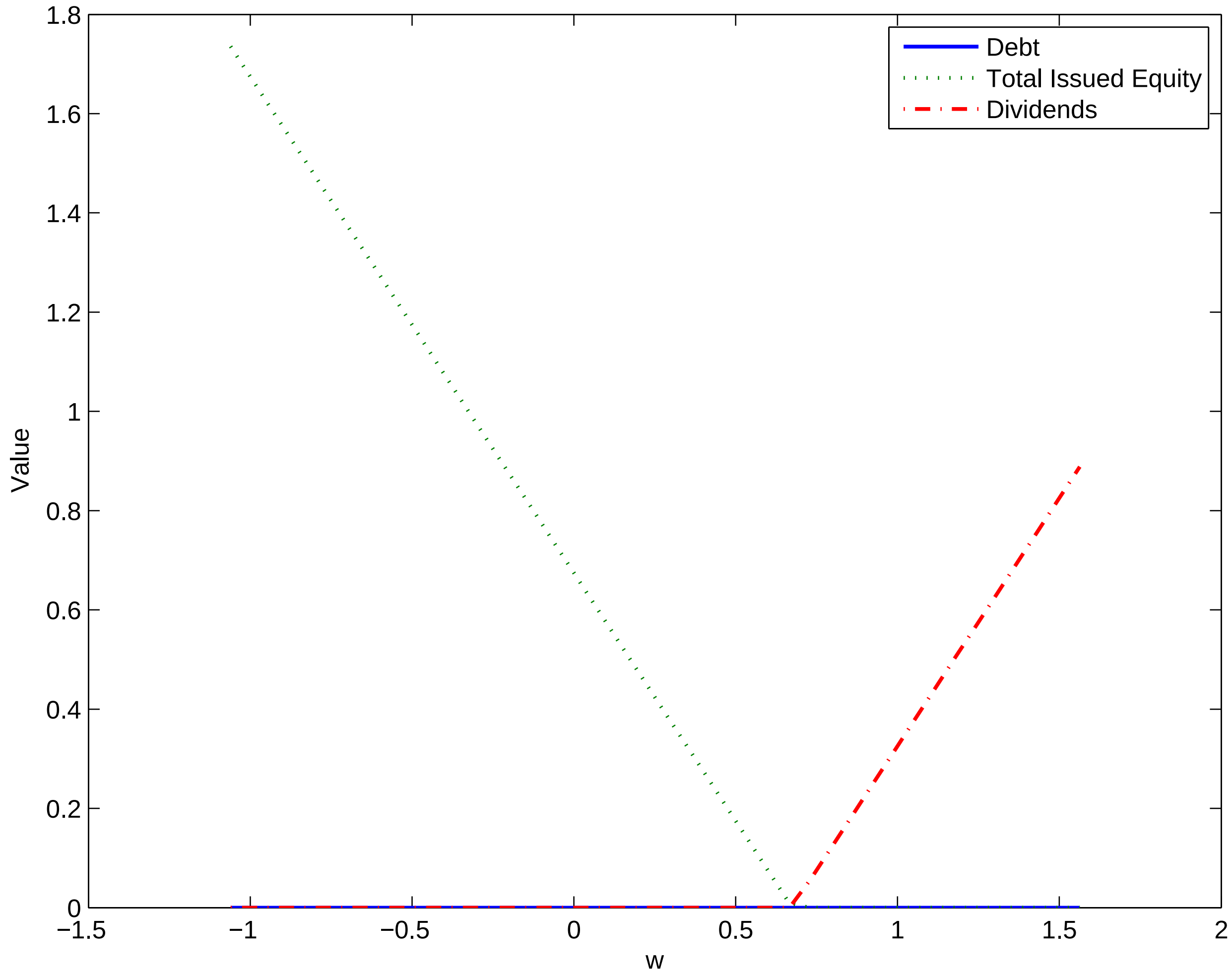
Proposition.

$$b_L^* \leq 0.$$

$$k_L^* > k_L^{FB}$$

Dividends and equity issuance fill remaining financing gap.

LCSE Financing policies - low value of θ

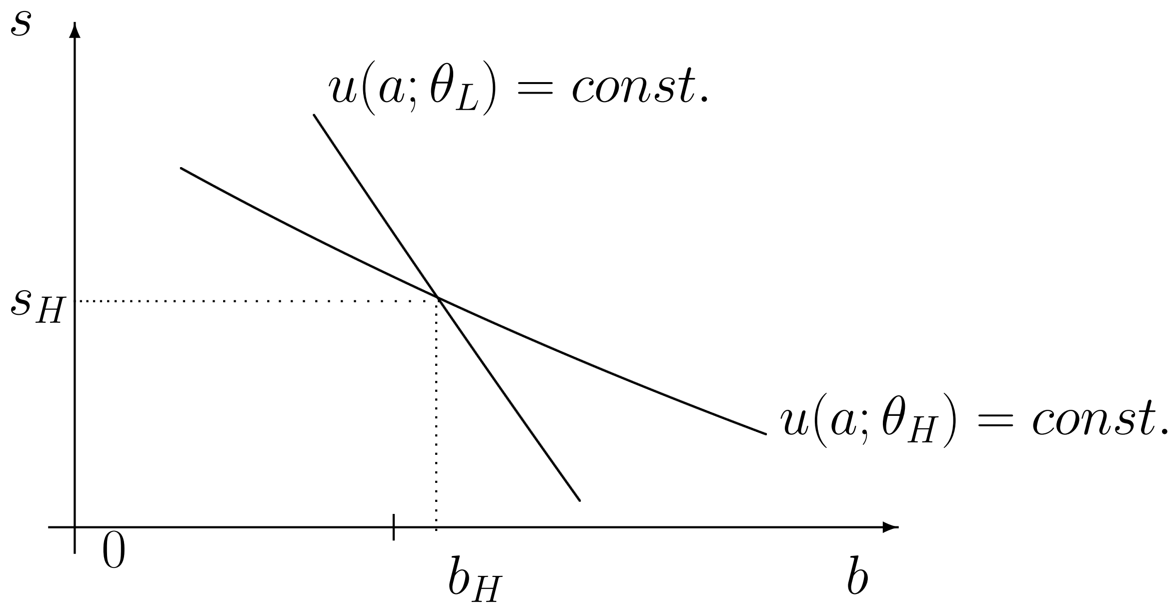


High-Type Debt

$$\beta\gamma\left[\int_{\varepsilon^d_{HH}}^{\infty}[V'_H - 1]f(d\varepsilon) + \frac{\partial\varepsilon^d_{HH}}{\partial b_H}f(\varepsilon^d_{HH})\phi[(1-\delta)k^S_H + \pi(k^S_H, \theta_H, \varepsilon^d_{HH}) + |\underline{w}|]\right]$$

$$= \left[\frac{\mu\Omega(b^S_H, k^S_H, \theta_L)}{\lambda}\right]\left[\left|\frac{ds}{db}(a^S_H;\theta_L)\right| - \left|\frac{ds}{db}(a^S_H;\theta_H)\right|\right].$$

Debt-for-Equity Substitution as Positive Signal



High-Type Investment

$$
\begin{aligned}
1 = \beta\gamma &\left[\int_{\varepsilon^d_{HH}}^{\infty} V'_H \bullet [1 - \delta + \pi_k(k^S_H, \theta_H, \varepsilon)] f(d\varepsilon) \right] \\
&+ \beta\gamma(1-\phi) \int_{-\infty}^{\varepsilon^d_{HH}} [1 - \delta + \pi_k(k^S_H, \theta_H, \varepsilon)] f(d\varepsilon) \\
&- \beta\gamma \frac{\partial \varepsilon^d_{HH}}{\partial k_H} f(\varepsilon^d_{HH}) \phi [(1-\delta) k^S_H + \pi(k^S_H, \theta_H, \varepsilon^d_{HH}) + |\underline{w}|] \\
&+ \left[\frac{\mu \Omega(b^S_H, k^S_H, \theta_L)}{\lambda} \right] \left[\frac{ds}{dk}(a^S_H; \theta_H) - \frac{ds}{dk}(a^S_H; \theta_L) \right].
\end{aligned}
$$

Estimation Roadmap

- Use symmetric info model to estimate five technological parameters: $(\alpha, p, \bar{\varepsilon}, \theta_L, \theta_H)$.
- Match moments from a symmetric info economy to moments from Gomes (2001):
    - Mean capital stock
    - Mean and variance of investment rate
    - mean profit rate
    - Mean of Tobin's Q
- Do it by minimizing the average squared percentage error over the five moments.
- Use these moments to solve the model with asymmetric info for $\phi = 0.05$ and 0.15.

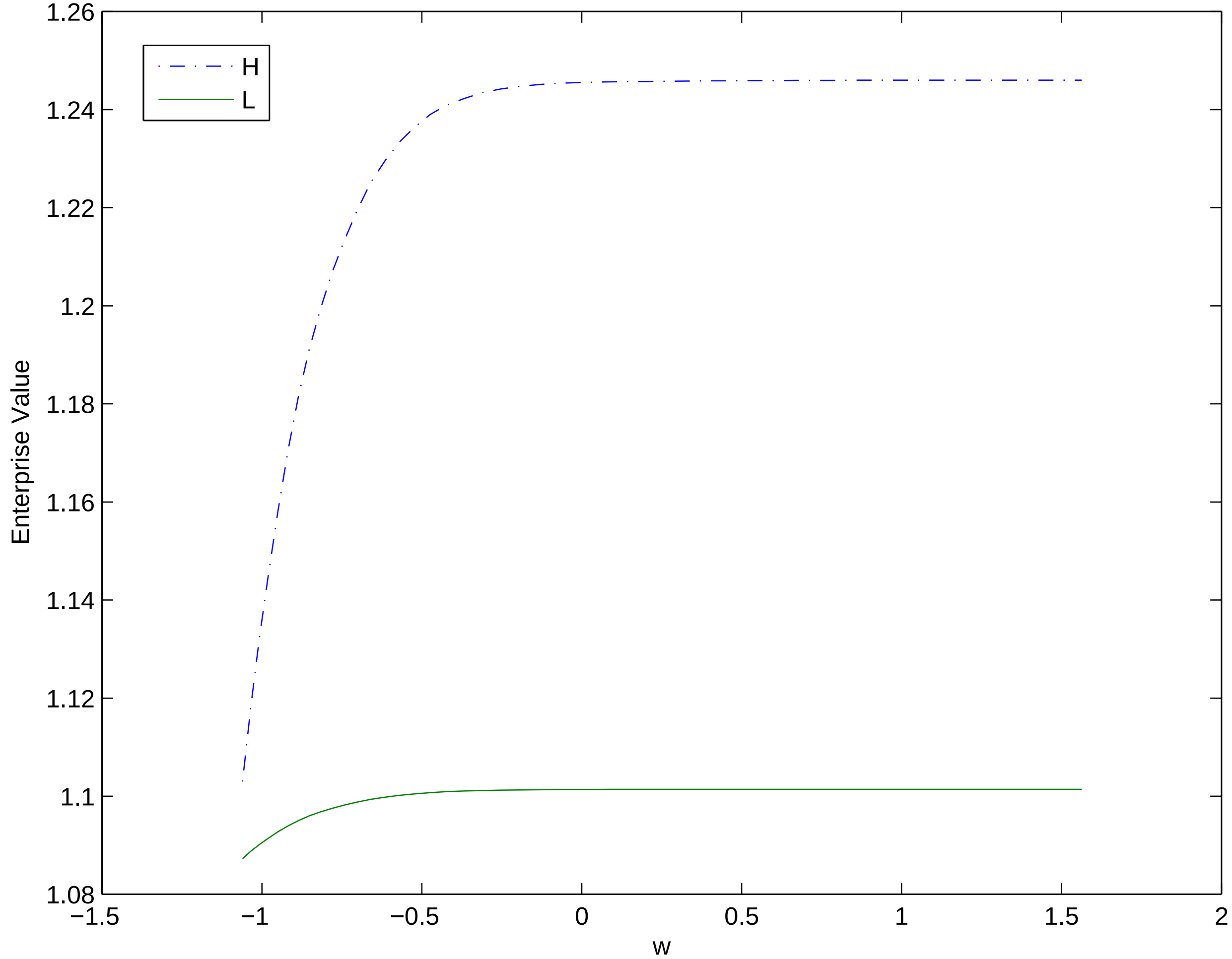
Parameter Values

Notation	Parameter Value	Definition
r	0.0400	Risk-Free Rate
$1-\gamma$	0.0500	Catastrophic Event Probability
δ	0.1000	Capital Depreciation Rate
$\overline{\varepsilon}$	0.8568	Mean of Public Shock
θ_L	0.3226	Low Type Productivity
θ_H	0.3851	High Type Productivity
$p(\theta_i\|\theta_i)$	0.9100	Type Persistence
α	0.6000	Capital Elasticity of Profits
ϕ	0.05 or 0.15	Proportional Bankruptcy Costs

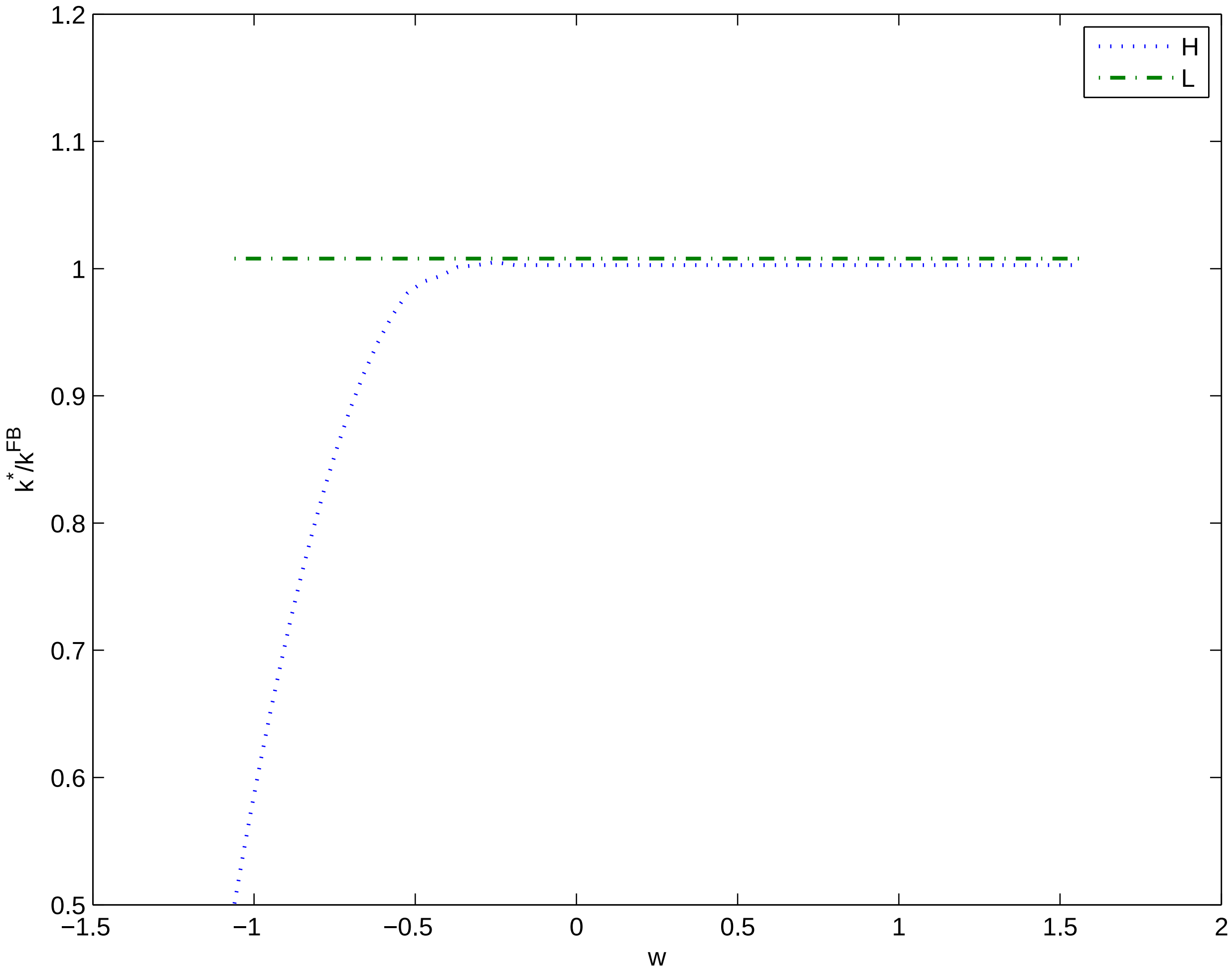
Model and Data Moments

	Data	Symmetric Information Model	Signaling Model ($\phi = 0.05$)	Signaling Model ($\phi = 0.15$)
Average size (k_t)	0.8089	0.8556	0.7698	0.8125
Average investment rate $\left(\frac{i_{t+1}}{k_t}\right)$	0.1450	0.1091	0.1573	0.1588
Variance of investment rate	0.0193	0.0198	0.0516	0.0392
Mean Tobin's q $\left(\frac{v_{t+1}+b_t}{k_t}\right)$	1.5600	1.4153	1.8825	1.7763
Average profit rate $\left(\frac{\pi_t}{k_t}\right)$	0.2920	0.3246	0.3457	0.3354
Average market leverage $\left(\frac{\rho_t}{\rho_t+\Omega_t}\right)$	0.1204	0.0000	0.1430	0.1196
Average payout ratio $\left(\frac{d_t}{\pi_t-\rho_t+b_t}\right)$	0.2226	1.0000	0.3121	0.3170

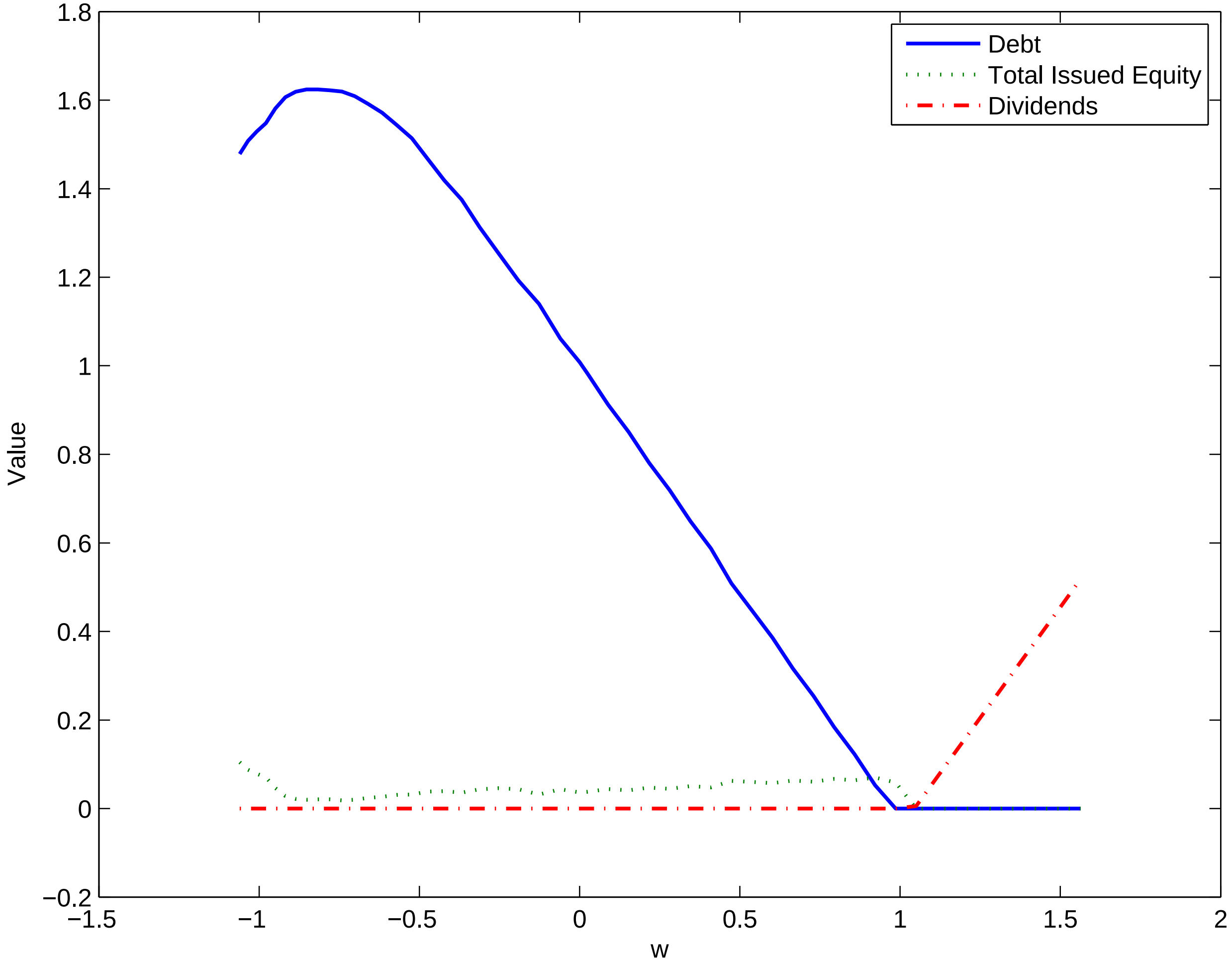
Enterprise Value Functions: $V_i(w) - w$



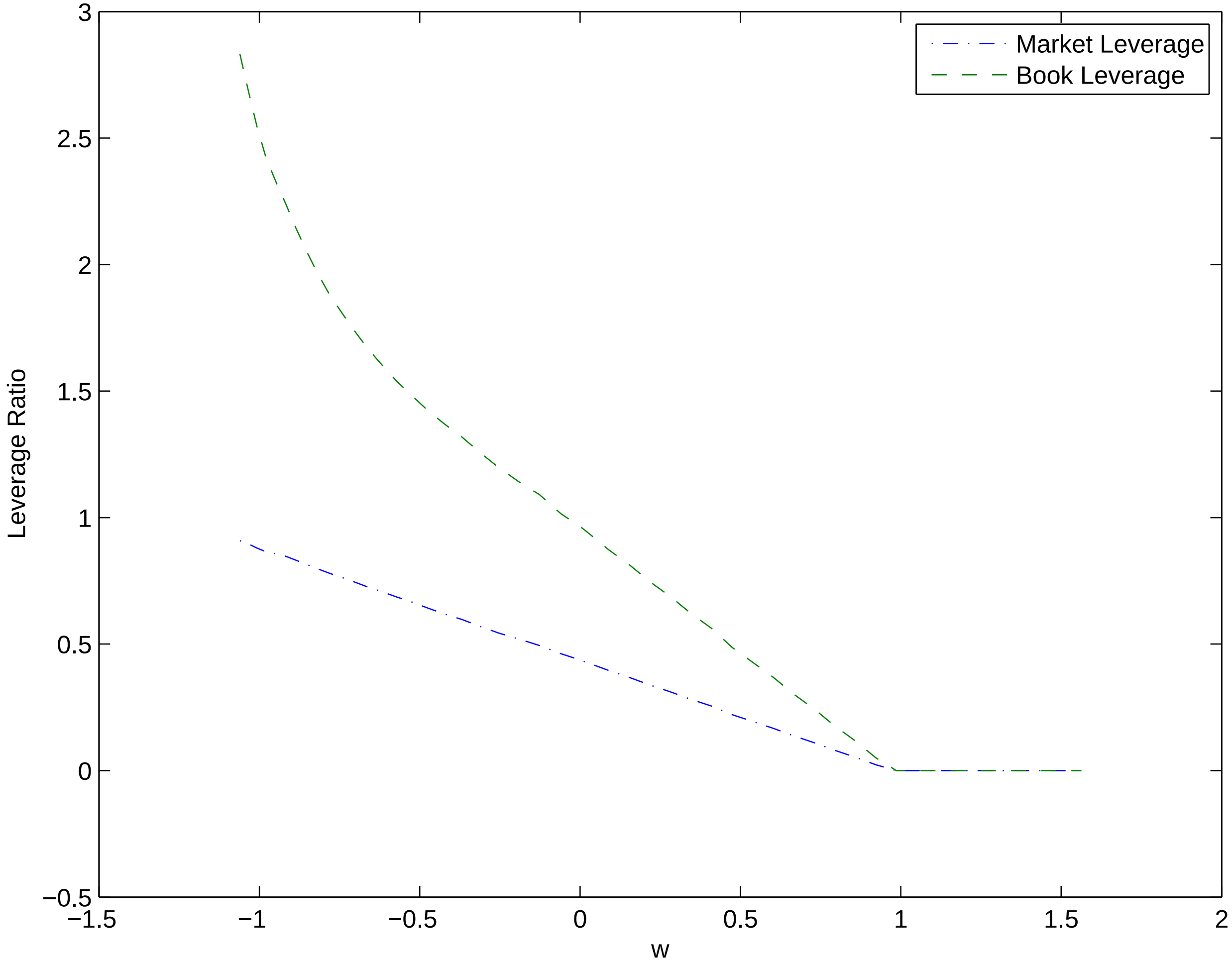
LCSE Capital allocations



LCSE Financing policies - high value of θ



Book and Market Leverage



Wealth Sensitivity Regressions

Parameter	Wealth Sensitivity	Std.	Wealth Sensitivity	Std.
	$\phi = 0.05$		$\phi = 0.15$	
Market leverage $\left(\frac{\rho_t}{\rho_t+\Omega_t}\right)$	-0.2219	0.0872	-0.2821	0.0947
Book leverage $\left(\frac{\rho_t}{k_t}\right)$	-0.2642	0.0806	-0.3096	0.1096
Dividends (d_t)	0.4182	0.0687	0.4147	0.0672
Growth rate $\left(\frac{v_{t+1}-v_t}{v_t}\right)$	-0.6277	0.2663	-0.7147	0.2957

Announcement Effect Regressions

- Abnormal announcement return $AR_t = (\Gamma_{\theta_t}(w_t) - V_{\theta_{t-1}}(w_t))/V_{\theta_{t-1}}(w_t)$

$\phi = 0.05$			$\phi = 0.15$		
Investment Rate	$\frac{\rho_t}{k_t}$	$1_{\{\rho_{t-1}=0,\rho_t>0\}}\frac{\rho_t}{k_t}$	Investment Rate	$\frac{\rho_t}{k_t}$	$1_{\{\rho_{t-1}=0,\rho_t>0\}}\frac{\rho_t}{k_t}$
0.1477	-	-	0.1511		-
(0.0245)	-	-	(0.0178)		-
-	0.0620	-	-	0.1616	-
-	(0.0400)	-	-	(0.1238)	-
-	0.0597	0.2822	-	0.0687	0.2891
-	(0.0449)	(0.0721)	-	(0.0775)	(0.0738)
0.1495	0.0039	-	0.1475	0.0211	-
(0.0487)	(0.0724)	-	(0.0227)	(0.0413)	-
0.1411	0.0329	0.0127	0.1411	0.0329	0.0127
(0.0405)	(0.0914)	(0.1296)	(0.0405)	(0.0914)	(0.1296)

Conclusion

- First dynamic structural model with signaling (hidden information) as opposed to trade-off theory or hidden action.
- Simple computational algorithm to determine equilibrium.
- Repeated signaling leads to precautionary saving, overinvestment by low type and underinvestment by high type.
- Equilibrium evolves from pooling to separating.
- Default risk for given debt contingent upon equilibrium.