"How Costly is External Financing? Evidence from a Structural Estimation"
Christopher A. Hennessy and Toni M. Whited (2007)
Journal of Finance

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Motivation

- Modigliani-Miller Irrelevance Theorem (1958, 1963)

  In frictionless world, financing decisions like capital structure (debt vs. equity), payout policy, cash holding, etc. do not matter.

- Why? No arbitrage

- MM assumes there are no financial friction:
  - Perfect and complete capital markets
  - No taxes
  - Bankruptcy is not costly
  - Capital structure does not affect investment policy or cash flows
  - Symmetric information

Hennessy and Whited (2007)

- HW (2007) formulate a dynamic structural model of optimal financial and investment policy for a firm facing
  - Corporate and personal taxes
  - Bankruptcy costs
  - Costs to issue external equity
- HW (2007) estimate parameters describing production technology and financial frictions using simulated method of moments (SMM)
- HW (2007) is seminal paper that uses SMM in corporate finance

Outline

Environment - Production and Debt

- Estimated parameters in red
- Firm produces with k capital
- Productivity follows discretized AR(1) process in logs:

$$\ln z' = \rho \ln z + \sigma_\varepsilon \varepsilon$$

  where $\varepsilon \sim N(0,1)$. Tauchen discretization $\implies Q(z,z')$ transition probability and finite min/max
- Operating profits are zk^α where $\alpha \in (0,1)$
- Firm also has b net debt
  - $b > 0$ is one-period defaultable debt with interest rate $\tilde{r}$ that depends on k, b, and z (not contingent on z')
  - $b \leq 0$ is cash that returns risk-free rate r
- Firm defaults on debt if continuation value is negative

Environment - Taxes and Equity Issuance

- Personal tax rate $\tau_i \implies$ firms discounts using $\frac{1}{1+r(1-\tau_i)}$
- Corporate taxable income is operating profits net of depreciation and interest:

$$y \equiv zk^{\alpha} - \delta k - \tilde{r}(k, b, z^{-})b$$

- Corporate tax schedule has "kink" around zero

$$T^C(y) \equiv \begin{cases} \tau_c^{+} y, & \text{if } y > 0 \\ \tau_c^{-} y, & \text{if } y \leq 0 \end{cases}$$

- Shareholder tax liability on dividend:

$$T^d(div) = \int_0^{div} \tau_d(x)dx \text{ where } \tau_d(x) \equiv \bar{\tau}_d * [1 - e^{-\phi x}]$$

- Firm pays fixed, linear, and quadratic costs for external equity issuance:

$$\Lambda(iss) \equiv \begin{cases} \lambda_0 + \lambda_1 iss + \lambda_2 iss^2, & \text{if } iss > 0 \\ 0, & \text{if } iss \leq 0 \end{cases}$$

“Naive” Way to Write Firm Value Function

$$V(k,b,z,z^-) = \max_{(k',b')} \Bigg\{ \underbrace{w+b'-k'}_{\text{cash dividend } (+) \text{ or equity issuance } (-)} - \underbrace{T^d(w+b'-k')}_{\text{taxes on cash dividend}} - \underbrace{\Lambda(-(w+b'-k'))}_{\text{equity issuance cost}}$$

$$+ \frac{1}{1+r(1-\tau_i)} E\Big[\underbrace{\max\{V(k',b',z',z),0\}}_{\text{if } V(\cdot) \text{ is } (-) \implies \text{ default}}\Big]\Bigg\}$$

where

$$\underbrace{y}_{\text{taxable corporate income}} \equiv \underbrace{zk^\alpha}_{\text{operating profits}} - \underbrace{\delta k}_{\text{depreciation}} - \underbrace{\tilde{r}(k,b,z^-)b}_{\text{interest on debt}}$$

$$\underbrace{w}_{\text{realized net worth}} \equiv \underbrace{y - T^C(y)}_{\text{after-tax corporate income}} + \underbrace{k}_{\text{capital}} - \underbrace{b}_{\text{debt principal}}$$

Smarter Way to Write Firm Value Function

$$
\begin{aligned}
V(w,z) = \max_{(k',b')} \Bigg\{ & \underbrace{w+b'-k'}_{\text{cash dividend } (+) \text{ or equity issuance } (-)} - \underbrace{T^d(w+b'-k')}_{\text{taxes on cash dividend}} - \underbrace{\Lambda(-(w+b'-k'))}_{\text{equity issuance cost}} \\
& + \frac{1}{1+r(1-\tau_i)} E\Big[\underbrace{\max\{V(w',z'),0\}}_{\text{if } V \text{ is } (-) \text{ can default}}\Big] \Bigg\}
\end{aligned}
$$

$$
\text{where} \quad \underbrace{y'}_{\text{taxable corporate income}} \equiv \underbrace{z'(k')^{\alpha}}_{\text{operating profits}} - \underbrace{\delta k'}_{\text{depreciation}} - \underbrace{\tilde{r}(k',b',z)b'}_{\text{interest on debt}}
$$

$$
\underbrace{w'}_{\text{realized net worth}} \equiv \underbrace{y' - T^C(y')}_{\text{after-tax corporate income}} + \underbrace{k'}_{\text{capital}} - \underbrace{b'}_{\text{debt principal}}
$$

Default and Interest Rates

- Firm defaults on debt if w below z'-specific threshold:

$$\underline{w}(z') = V^{-1}(0, z') < 0 \implies z_d(k', b', z) \text{ threshold}$$

- If firm defaults, outside investor gets recovery value

$$R(k', z') = \underbrace{(1-\xi)(1-\delta)k'}_{\text{depreciated capital net of deadweight bankruptcy cost}} + \underbrace{z'(k')^{\alpha}}_{\text{operating profit}} - \underbrace{T_c(z'(k')^{\alpha} - \delta k')}_{\text{corporate tax bill}} - \underbrace{\underline{w}(z')}_{\text{going-concern}}$$

- Interest rates on debt determined by zero-profit condition for outside investor

$$\underbrace{(1 + r(1-\tau_i))b'}_{\text{risk-free investment}} = \underbrace{(1 + (1-\tau_i)\tilde{r}(k', b', z))b' \int_{z_d(k',b',z)}^{\bar{z}} Q(z, dz')}_{\text{return on non-defaulted debt}} + \underbrace{\int_{\underline{z}}^{z_d(k',b',z)} R(k', z') Q(z, dz')}_{\text{return on defaulted debt}}$$

Computation

- No closed form solution $\implies$ solve numerically
- Computational strategy:
  - Guess $\tilde{r}(k', b', z) = r$
  - Solve V with value function iteration
  - Compute $z_d(k', b', z)$
  - Update $\tilde{r}(k', b', z)$ using zero-profit condition
  - Repeat until convergence

Outline

External Parameters from Related Literature

Parameter	Value
$\bar{\tau}_d$	0.12
τ_i	0.29
τ_c^+	0.40
τ_c^-	0.20
r	0.025
δ	0.15

- Notice $\tau_c^+ > \tau_c^- \implies$ corporate taxes larger on positive income than rebate for corporate losses

Moments Selection

Parameter	Description	Moments
α	Profit fn. curvature	Var. of investment
λ_i	Ex. equity iss. costs	Freq. negative debt
		Cov. equity iss. and inv.
λ_0	Fixed cost	Freq. and mean equity iss.
λ_2	Quadratic cost	Var. of equity iss.
ξ	Bankruptcy deadweight cost	Mean net debt-to-assets
		Cov. of lev. and inv.
ϕ	Shareholder tax liab. curvature	Payout ratio
		Var. of dividends
σ_ε	Productivity shock var.	SD of shock to inc.-to-assets
ρ	Productivity persistence	Serial cor. of inc.-to-assets

- High $\lambda_0 \implies$ fewer larger equity issuances
- Freq. negative debt $\implies$ precautionary motion for saving
- Cov. of equity iss. and investment informs about equity position in pecking order
- Cov. of lev. and investment informs about debt position in pecking order

Moments and Estimated Parameters using SMM

Parameter	Estimates (HW)	SE (HW)
α	0.627	(0.219)
λ_0	0.598	(0.233)
λ_1	0.091	(0.026)
λ_2	0.0004	(0.0008)
ξ	0.104	(0.059)
ϕ	0.732	(0.844)
σ_ε	0.118	(0.042)
ρ	0.684	(0.349)

	Data Moments	Simulated Moments
Mean Equity Iss./Assets	0.0892	0.0963
Var of Equity Iss./Assets	0.0911	0.0847
Var of Inv./Assets	0.0068	0.0117
Freq of Equity Iss.	0.1751	0.2305
Payout Ratio	0.2226	0.2026
Freq of Negative Debt	0.3189	0.3258
Var of Dividends	0.0013	0.0037
Mean Debt-Assets Ratio	0.1204	0.1104
Cov of Inv. and Equity Iss.	0.0004	0.0005
Cov of Inv. and Lev.	-0.0018	-0.0025
Serial Cor of Inc./Assets	0.5121	0.5661
SD of Inc./Assets Shocks	0.1185	0.1057

- Good fit, but biggest problem is overestimate of variance of dividends (consistent with lit.)

Outline

Replication Issues

1. Discount bond prices are bounded whereas interest rates are not:

$$V(w,z) = \max_{(k',b')} \Bigg\{ \underbrace{w + b'q(k',b',z) - k'}_{\text{dividend if } (+) \text{ or equity issuance if } (-)} - \underbrace{T^d(w + b'q(k',b',z) - k')}_{\text{taxes on dividend}}$$

$$- \underbrace{\Lambda(-(w + b'q(k',b',z) - k'))}_{\text{equity issuance cost}} + \frac{1}{1 + r(1-\tau_i)} E\Big[\underbrace{\max\{V(w',z'),0\}}_{\text{if } V \text{ is } (-)\text{, default}} |z \Big] \Bigg\}$$

$$\text{where} \quad \underbrace{y'}_{\text{taxable income}} \equiv \underbrace{z'(k')^{\alpha}}_{\text{operating profits}} - \underbrace{\delta k'}_{\text{depreciation}} - \underbrace{(1 - q(k',b',z))b'}_{\text{interest on debt}}$$

$$\underbrace{w'}_{\text{realized net worth}} \equiv \underbrace{y' - T^C(y')}_{\text{after-tax corporate income}} + \underbrace{k'}_{\text{capital}} - \underbrace{q(k',b',z)b'}_{\text{debt principal}}$$

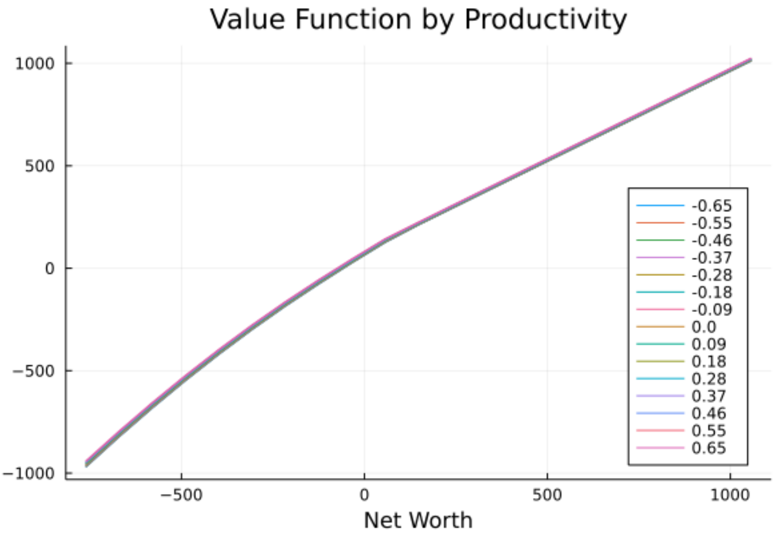
2. What is the w grid?
   - HW (2007) are specific about z, b, k grids, but quiet about the w grid
   - My solution: Loop over z, b, k grids and solve w for $q = 0$ and $q = 1/(1+r)$, then linear interpolate between min and max
3. No contraction mapping for bond prices $\implies$ update q guess slowly
4. Compustat data revisions
5. Unclear data appendix: number of obs. were either 2x or 0.5x

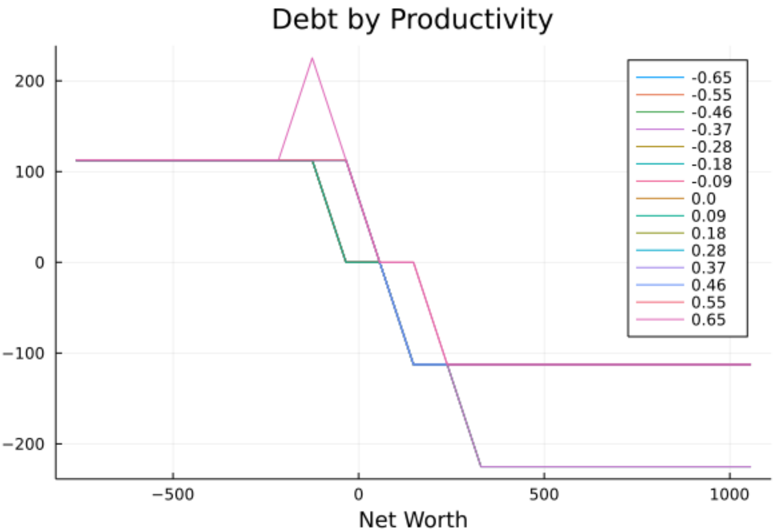
Model Replication

- I coded up model and solved it using HW (2007) estimated parameters

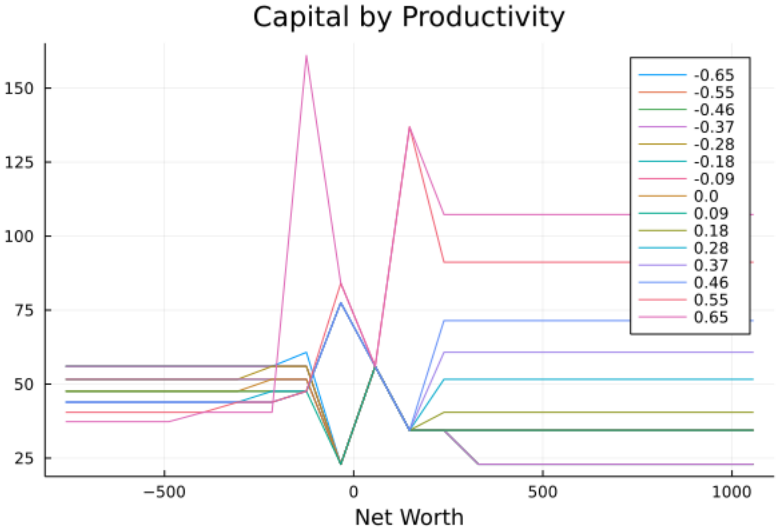
	Simulated Moments (HW)	Simulated Moments (AHV)
Mean Equity Iss./Assets	0.0963	0.0406
Var of Equity Iss./Assets	0.0847	0.0005
Var of Inv./Assets	0.0117	0.0047
Freq of Equity Iss.	0.2305	1.0000
Payout Ratio	0.2026	0.0000
Freq of Negative Debt	0.3258	1.0000
Var of Dividends	0.0037	0.0000
Mean Debt-Assets Ratio	0.1104	-1.0333
Cov of Inv. and Equity Iss.	0.0005	0.0005
Cov of Inv. and Lev.	-0.0025	0.0017
Serial Cor of Inc./Assets	0.5661	0.6666
SD of Inc./Assets Shocks	0.1057	0.0326

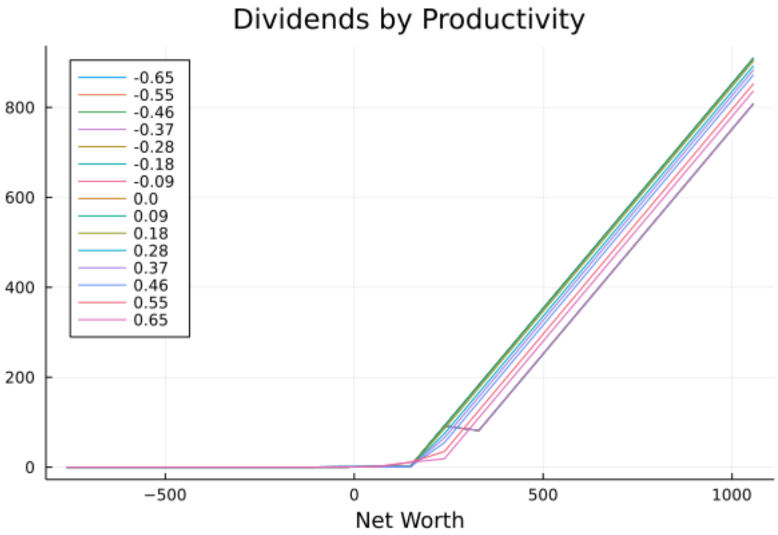
- Too much equity issuance and too little dividends
- Too much negative debt (e.g., corporate savings)

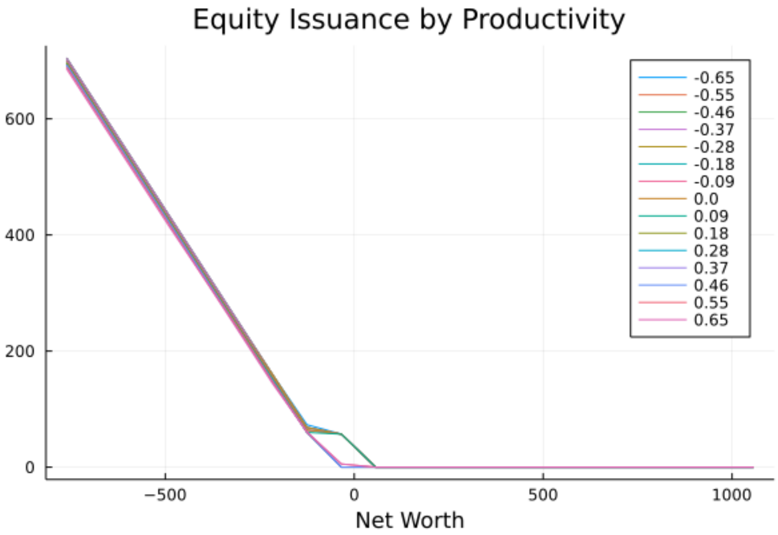

Value Function by Productivity
1000
500
0
−500
−1000
−500
0
500
1000
Net Worth
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65

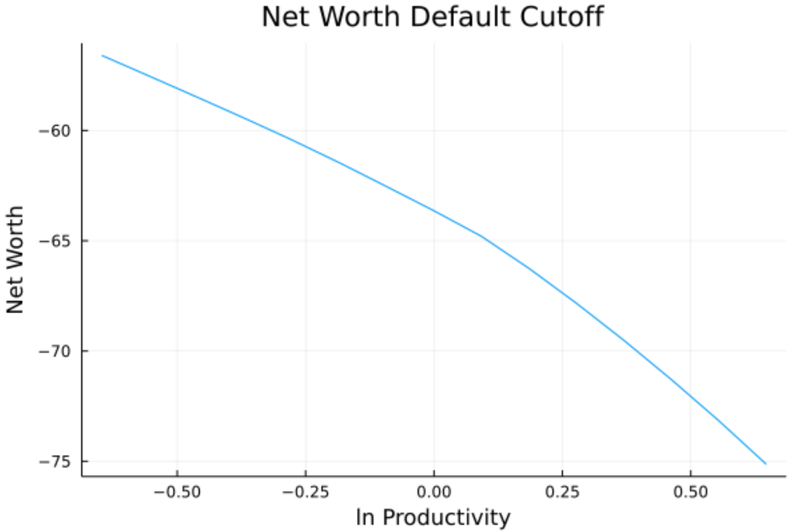


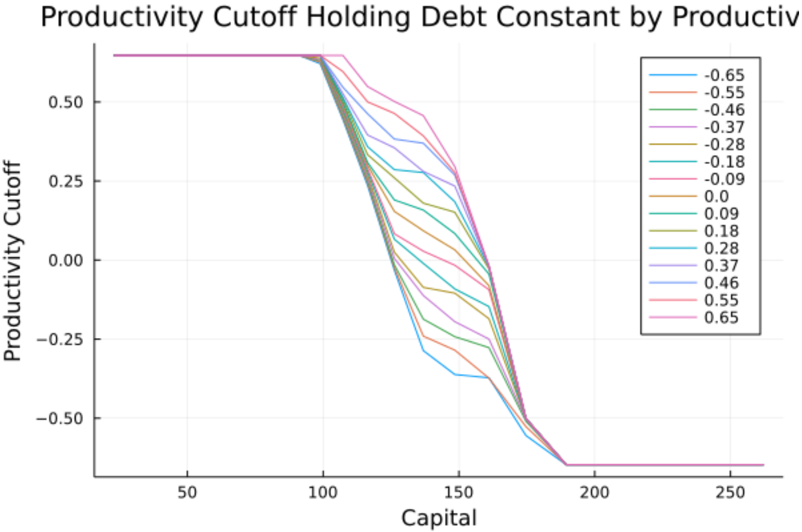
Debt by Productivity
200
100
0
−100
−200
−500
0
500
1000
Net Worth
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65

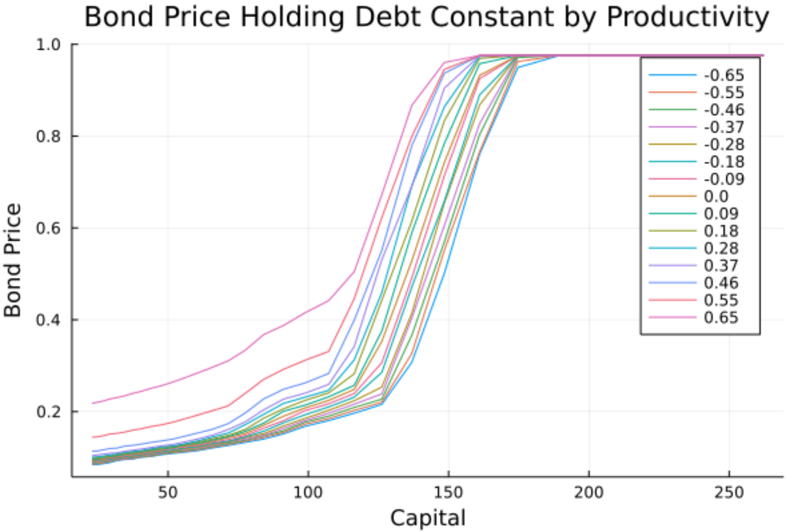

Capital by Productivity
150
125
100
75
50
25
−500
0
500
1000
Net Worth
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65


Dividends by Productivity
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65
800
600
400
200
0
−500
0
500
1000
Net Worth


Equity Issuance by Productivity
600
400
200
0
−500
0
500
1000
Net Worth
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65


Net Worth Default Cutoff
Net Worth
−60
−65
−70
−75
−0.50
−0.25
0.00
0.25
0.50
ln Productivity


Productivity Cutoff Holding Debt Constant by Productiv
Productivity Cutoff
Capital
0.50
0.25
0.00
−0.25
−0.50
50
100
150
200
250
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65


Bond Price Holding Debt Constant by Productivity
Bond Price
Capital
1.0
0.8
0.6
0.4
0.2
50
100
150
200
250
-0.65
-0.55
-0.46
-0.37
-0.28
-0.18
-0.09
0.0
0.09
0.18
0.28
0.37
0.46
0.55
0.65

Data Replication

- I recomputed data moments for original period and recent period

	Data Moments (HW)	Data Moments (AHV)	Data Moments (AHV)
Sample Period	(1988-2001)	(1988-2001)	(2010-2019)
Mean Equity Iss./Assets	0.0892	0.0734	0.0546
Var of Equity Iss./Assets	0.0911	0.0325	0.0229
Var of Inv./Assets	0.0068	0.0035	0.0024
Freq of Equity Iss.	0.1751	0.6446	0.683
Payout Ratio	0.2226	0.4979	0.5906
Freq of Negative Debt	0.3189	0.3519	0.4565
Var of Dividends	0.0013	0.0012	0.0022
Mean Debt-Assets Ratio	0.1204	0.1158	0.0362
Cov of Inv. and Equity Iss.	0.0004	0.0004	-0.0001
Cov of Inv. and Lev.	-0.0018	0.0008	0.0024
Serial Cor of Inc./Assets	0.5121	0.3924	0.4132
SD of Inc./Assets Shocks	0.1185	0.2582	0.2034

- Comparing column 1 and column 2:
  - Var of equity iss./asset too small
  - Too much equity issuance and too high payout ratio
  - Cov. of inv. and lev. changes sign
  - Serial cor. of inc./assets too high and sd of shocks too high
- Comparing column 2 and column 3:
  - Higher dividend variance $\Longrightarrow$ change in ϕ?
  - Lower mean debt-to-assets ratio and cov. of inv. and lev. changed sign $\Longrightarrow$ change in ξ?