A Robustness Check on Debt and the Pecking Order Hypothesis with Asymmetric Information

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Abstract
Daniel and Titman (1995) examined the incentives of firms to signal their values prior to making a new equity offering. By analyzing this issue within a simple framework that encompasses a number of models in the literature, they were able to judge the relative efficiency of various signals that have been proposed. Although their analyses offer valuable insights, the robustness of their model has yet to be checked. This paper examines the parametric assumptions of their model in the section on debt and the pecking order hypothesis. We first generalize the assumptions in the example by Daniel and Titman (1995) to allow for continuous-state of nature. We then derive the resulting closed-form solution for the equilibrium payoffs to the original shareholders of both types of firms under different beliefs. Although we only examine the robustness of a particular setting, our methodology can be applied to other settings.

Keywords: financing decisions, pecking order hypothesis, asymmetric information, signaling, robustness

1. Introduction
The objective of the manager of the firm is to maximize the terminal value of the original owners’ claim to the firm’s assets. Giammarino and Neave (1982) set up a model in which the managers and investors share the same information about everything except risk. In this case, equity issues dominate debt issues, because the only time managers want to issue debt is when they know the firm is riskier than investors think. Investors, realizing this, refuse to buy. Only equity, or perhaps a convertible security, is issued in equilibrium (see Myers & Majluf, 1984). Daniel and Titman (1995) provides a numerical example that illustrates what Giammarino and Neave (1982) have shown: if managers have private information about only cash flow variance, then the pecking order will be reversed: firms will never issue debt. The numerical example in Daniel and Titman (1995) is reproduced in Table 1

Table 1. Debt-issuance equilibria: Original example from Daniel and Titman (1995)

<table>
<thead>
<tr>
<th>Model Parameters</th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>$p = 0.5$</td>
<td>$A_H = A_L = 10$</td>
<td>$I = 30$</td>
</tr>
<tr>
<td>$X_H^* = 50$, $X_H^* = 30$</td>
<td>$X_L^* = 80$, $X_L^* = 0$</td>
<td>$\pi_e = \pi_d = 0.5$</td>
</tr>
<tr>
<td>$E(X_H) = E(X_L) = \mu = 40$</td>
<td>$\text{Var}(X_H) = \sigma_H^2 = 100$</td>
<td>$\text{Var}(X_L) = \sigma_L^2 = 160$</td>
</tr>
</tbody>
</table>

Belief Set A: Don’t Take: None, Take: Both (pool)
Belief Set B: Don’t Take: H (Low variance), Take: L (High variance)

<table>
<thead>
<tr>
<th>TYPE</th>
<th>Don’t take</th>
<th>Take</th>
<th>TYPE</th>
<th>Don’t take</th>
<th>Take</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>10</td>
<td>13.33</td>
<td>H</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>L</td>
<td>10</td>
<td>26.67</td>
<td>L</td>
<td>10</td>
<td>20</td>
</tr>
</tbody>
</table>

In their setup, if the firm were to issue equity, there would be no adverse selection problem because the full-information value of a share of a type L’s equity would be the same as a type H’s (given the assumptions of risk neutrality and equal mean of both projects’ payoffs). Therefore, the original shareholders of both types
would issue equity at the full-information value and therefore capture the full NPV of the projects. However, if the firm chooses to issue debt, the full-information value of a type L bond would be lower, because a type L would default more often. In other words, if the types were observable, a type L would have to incur a notional debt obligation higher than the funds raised for the project. In their example, it is shown that both pooling and separating equilibrium are supported by investors' beliefs. However, since the payoff to the type H firm in both equilibria is lower than it would be if the firm issued equity, it is argued that type H firm would always issue equity: debt will be the dominated security.

The rest of the paper is organized as follows. Section 2 provides a brief review of related studies. Section 3 examines the robustness of the results in Daniel and Titman (1995) by generalizing their assumptions to allow for continuous-state of nature. Section 4 concludes.

2. Literature Review

Financing investments under asymmetric information is of great interest and importance both in theory and in practice. The information contents and implications of a firm’s financial decisions have been studied theoretically and empirically. On the theoretical front, Myers and Majluf (1984) consider the implications of adding the option of issuing debt to the firm’s strategy space, and conclude that there exists a pecking order in the issuance of securities. In their example, it is shown that both pooling and separating equilibrium are supported by investors’ beliefs. However, since the payoff to the type H firm in both equilibria is lower than it would be if the firm issued equity, it is argued that type H firm would always issue equity: debt will be the dominated security.

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Given the derived formulae, the robustness of Daniel and Titman’s conclusion to various parameters values in continuous-state setting can be easily examined. We found that their results are surprisingly robust to parameters values. However, one should keep in mind that this robustness is with respect to the parameters values only, because we are constraining in our model that debt and equity are the only instruments for financing the project. In the more realistic scenarios where other types of securities can also be used, the story will be a whole lot different from the simple pecking order or reverse pecking order theory. Figures 1 through 6 plot the values of interest from sensitivity analysis for each parameter. From each graph, we can easily determine any supported equilibrium/equilibria, and the relevant type H firm’s financing decision. Remarks on each of the Figures are provided following the Figures.

**Figure 1.** Sensitivity analysis with respect to probability of type-H firm

*Note.* For all values of $p$, separating equilibrium is supported. Roughly speaking, for $p \geq 0.4$, pooling equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.

**Figure 2.** Sensitivity analysis with respect to $(I-A)/A$

*Note.* For all values of $(I-A)/A$, pooling equilibrium is supported. Roughly speaking, for $(I-A)/A > 0$, separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.
Figure 3. Sensitivity analysis with respect to $NPV + I$

*Note.* For all values of $NPV + I$, pooling equilibrium is supported. Roughly speaking, only for $NPV + I \leq 40$, separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.

Figure 4. Sensitivity analysis with respect to $varH$

*Note.* For all values of $varH$, pooling equilibrium is supported. Roughly speaking, for $varH \leq 600$, separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.

Figure 5. Sensitivity analysis with respect to $varL$

*Note.* For all values of $varL$, pooling equilibrium is supported. Roughly speaking, for $varL \geq 600$, separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.
Figure 6. Sensitivity analysis with respect to \( \text{varH/\text{varL}} \).

Note. For all values of \( \text{varH/\text{varL}} \), pooling equilibrium is supported. Roughly speaking, for \( \text{varH/\text{varL}} \leq 0.2 \), separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.

**Notations for Figures 1 through 6:**

- \( BH \) = H-type firm shareholders’ expected payoffs under belief set A. (pooling)
- \( BL \) = L-type firm shareholders’ expected payoffs under belief set A. (pooling)
- \( DH \) = H-type firm shareholders’ expected payoffs under belief set B. (separating)
- \( DL \) = L-type firm shareholders’ expected payoffs under belief set B. (separating)
- \( A \) = Asset-in-place.
  
  A is also the value of the shareholders if the firm does not take the project.
- \( E \) = The value of the (old) shareholders if the project is financed by equity.
  
  E is the benchmark for H firm’s decision of whether to issue debt or equity.
- \( p \) = probability of type-H firm
- \( I \) = project investment
- NPV = net present value of the project
- \( \text{VarH} \) = variance of firm H project’s payoffs
- \( \text{VarL} \) = variance of firm L project’s payoffs

**4. Conclusion**

Daniel and Titman (1995) examined the incentives of firms to signal their values prior to making a new equity offering. By analyzing this issue within a simple framework that encompasses a number of models in the literature, they were able to judge the relative efficiency of various signals that have been proposed. Although their analyses offer valuable insights, the robustness of their model has yet to be checked. This paper examines the parametric assumptions of their model in the section on debt and the pecking order hypothesis. We first generalize the assumptions in the example by Daniel and Titman (1995) to allow for continuous-state of nature. We then derive the resulting closed-form solution for the equilibrium payoffs to the original shareholders of both types firms under different beliefs. We found that their results are surprisingly robust to parameters values. Although we only examine the robustness of a particular setting, our methodology can be applied to other settings, which is the major contribution of this paper to the existing studies.

**References**

Appendix A

Polling Notional Debt Obligation

\[ p = \text{prob. of H-type} \]
\[ 1 - p = \text{prob. of L-type} \]
\[ A_H = \text{asset - in - place of H-type} \]
\[ A_L = \text{asset - in - place of L-type} \]
\[ I = \text{project investment required} \]

NPV = expected value (net of I) of the project’s cash flows

\[ \mu = \text{expected value of the project’s gross cash flows} \]
\[ \mu = \text{NPV} + I \]
\[ X_H = \text{random payoff of the project from H-type} \]
\[ X_H \sim N(\mu, \sigma_H^2) \]
\[ X_L = \text{random payoff of the project from L-type} \]
\[ X_L \sim N(\mu, \sigma_L^2) \]
\[ \sigma_H^2 < \sigma_L^2 \]

\[ \Phi_H(.) = \text{CDF of } X_H \]
\[ f_H(.) = \text{PDF of } X_H \]
\[ \Phi_L(.) = \text{CDF of } X_L \]
\[ f_L(.) = \text{PDF of } X_L \]
\[ I_{PN} = \text{pooling notional debt obligation} \]

\[ I_{PN} \text{ solves } \]

\[ \text{prob}(\text{default}) \cdot E[\max(X + A, 0) | X < I - A] + \text{prob}(\text{solvent}) \cdot I_{PN} = I \]  

(1)

\[ \Leftrightarrow p \cdot \left[ \Phi_H(I - A_H) \cdot E[\max(X_H + A_H, 0) | X_H < I - A_H] + (1 - p) \cdot \Phi_L(I - A_L) \cdot E[\max(X_L + A_L, 0) | X_L < I - A_L] \right] + \left[ p \cdot [1 - \Phi_H(I - A_H)] + (1 - p) \cdot [1 - \Phi_L(I - A_L)] \right] \cdot I_{PN} = I \]  

(2)

Note that:

\[ E[\max(X_H + A_H, 0) | X_H < I - A_H] \]

\[ = \int_{-\infty}^{\infty} \max(X_H + A_H, 0) \cdot f_H(x_H | x_H < I - A_H) \, dx_H \]

\[ = \int_{-\infty}^{\infty} \max(X_H + A_H, 0) \cdot f_H(x_H) \, dx_H \]

\[ = \frac{1}{\Phi_H(I - A_H)} \int_{-\infty}^{I - A_H} X_H + A_H \cdot f_H(x_H) \, dx_H \]

\[ = \frac{1}{\Phi_H(I - A_H)} \left[ \int_{-\infty}^{I - A_H} (X_H + A_H) \cdot f_H(x_H) \, dx_H - \int_{-\infty}^{I - A_H} (X_H + A_H) \cdot f_H(x_H) \, dx_H \right] \]

\[ = \frac{1}{\Phi_H(I - A_H)} \left[ \left[ A_H \cdot \Phi_H(I - A_H) + T_{cI - A_H} \right] - \left[ A_H \cdot \Phi_H(-A_H) + T_{cA_H} \right] \right] \]

\[ = \frac{1}{\Phi_H(I - A_H)} \left[ T_{cI - A_H} - T_{cA_H} \right] + \frac{1}{\Phi_H(I - A_H)} \left[ \Phi_H(I - A_H) - \Phi_H(-A_H) \right] \cdot A_H \]

(3)

where \( T_{cI - A_H} \) = \( \int_{-\infty}^{I - A_H} X_H \cdot f_H(x_H) \, dx_H \)

\[ = \mu - \left\{ \mu \cdot \Phi_H \left( \frac{I - A_H - \mu}{\sigma_H} \right) \right\} + \sigma_H^2 \cdot f_H(I - A_H) \]

is a lower truncated mean of \( X_H \)

\[ T_{cA_H} = \int_{-\infty}^{A_H} X_H \cdot f_H(x_H) \, dx_H \]

\[ = \mu - \left\{ \mu \cdot \Phi_H \left( \frac{-A_H - \mu}{\sigma_H} \right) \right\} + \sigma_H^2 \cdot f_H(-A_H) \]

is a lower truncated mean of \( X_L \)

Similarly,

\[ E[\max(X_L + A_L, 0) | X_L < I - A_L] = \frac{1}{\Phi_L(I - A_L)} \left[ T_{cI - A_L} - T_{cA_L} \right] + \frac{1}{\Phi_L(I - A_L)} \left[ \Phi_L(I - A_L) - \Phi_L(-A_L) \right] \cdot A_L \]  

(4)

Plug (3) and (4) into (2), and define:

\[ Q_H = \left[ T_{cI - A_H} - T_{cA_H} \right] + \left[ \Phi_H(I - A_H) - \Phi_H(-A_H) \right] \cdot A_H \]

\[ Q_L = \left[ T_{cI - A_L} - T_{cA_L} \right] + \left[ \Phi_L(I - A_L) - \Phi_L(-A_L) \right] \cdot A_L \]
Similarly, we have

\[ p \cdot Q_H + (1 - p) \cdot Q_L + \left\{ p \cdot \left[ 1 - \Phi_H(I - A_H) \right] + (1 - p) \cdot \left[ 1 - \Phi_L(I - A_L) \right] \right\} \cdot I_{PN}^* = I \]

\[ \Rightarrow I_{PN}^* = \frac{I - \left[ p \cdot Q_H + (1 - p) \cdot Q_L \right]}{p \cdot \left[ 1 - \Phi_H(I - A_H) \right] + (1 - p) \cdot \left[ 1 - \Phi_L(I - A_L) \right]} \quad (5) \]

**Appendix B**

(Old) shareholder’s expected value if the firms take the project while under belief set A

Belief Set A: both types of firms issue debt with notional debt obligation \( I_{PN}^* \)

\( B_H = H \) - type firm’s (old) shareholders’ expected value under Belief Set A

\( B_L = L \) - type firm’s (old) shareholders’ expected value under Belief Set A

\[ \begin{align*}
B_H &= E \left[ \max \left( A_H + X_H - I_{PN}^* ; 0 \right) \right] \\
&= \int_{-\infty}^{\infty} \left[ \max \left( A_H + X_H - I_{PN}^* ; 0 \right) \right] f_H(X_H) \, dX_H \\
&= \int_{I_{PN}^* - A_H}^{\infty} \left( A_H + X_H - I_{PN}^* \right) f_H(X_H) \, dX_H \\
&= \int_{I_{PN}^* - A_H}^{\infty} A_H \, f_H(X_H) \, dX_H + \int_{I_{PN}^* - A_H}^{\infty} X_H \cdot f_H(X_H) \, dX_H \\
&= \left[ 1 \cdot \Phi_H \left( I_{PN}^* - A_H \right) \right] \left( A_H - I_{PN}^* \right) + T_{> I_{PN}^* - A_H} \\
\end{align*} \]

where \( T_{> I_{PN}^* - A_H} = \int_{I_{PN}^* - A_H}^{\infty} X_H \cdot f_H(X_H) \, dX_H \)

\[ = \mu \cdot \left[ 1 - \Phi_H \left( \frac{I_{PN}^* - A_H - \mu}{\sigma_H} \right) \right] + \sigma_H^2 \cdot f_H \left( I_{PN}^* - A_H \right) \]

Similarly,

\[ \begin{align*}
B_L &= E \left[ \max \left( A_L + X_L - I_{PN}^* ; 0 \right) \right] \\
&= \left[ 1 \cdot \Phi_L \left( I_{PN}^* - A_L \right) \right] \left( A_L - I_{PN}^* \right) + T_{> I_{PN}^* - A_L} \\
\end{align*} \]

where \( T_{> I_{PN}^* - A_L} = \int_{I_{PN}^* - A_L}^{\infty} X_L \cdot f_L(X_L) \, dX_L \)

\[ = \mu \cdot \left[ 1 - \Phi_L \left( \frac{I_{PN}^* - A_L - \mu}{\sigma_L} \right) \right] + \sigma_L^2 \cdot f_L \left( I_{PN}^* - A_L \right) \]
Appendix C
(Old) shareholder’s expected value if the firms take the project while under Belief Set B

Belief Set B: H-type does not take the project.
L-type takes the project by issuing debt with notional obligation \( I_{NL}^* \)

\[ D_H = H \text{- type firm}'s \ (old) \ shareholders' expected value under Belief Set B \]
\[ D_L = L \text{- type firm}'s \ (old) \ shareholders' expected value under Belief Set B \]

\( I_{NL}^* \) can be obtained by setting \( p = 0 \) in equation (5).

Hence,
\[ I_{NL}^* = \frac{I - Q_L}{1 - \Phi_L(I - A_L)} \quad (8) \]

By the same derivations as in (6) and (7), we have
\[ D_H = E\left[ \max\left( A_H + X_H - I_{NL}^*, 0 \right) \right] = \left[ 1 - \Phi_H(I_{NL}^* - A_H) \right] (A_H - I_{NL}^*) + T_{> I_{NL}^* - A_H} \quad (9) \]

And
\[ D_L = E\left[ \max\left( A_L + X_L - I_{NL}^*, 0 \right) \right] = \left[ 1 - \Phi_L(I_{NL}^* - A_L) \right] (A_L - I_{NL}^*) + T_{> I_{NL}^* - A_L} \quad (10) \]

where
\[ T_{> I_{NL}^* - A_H} = \int_{I_{NL}^* - A_H}^\infty X_H \cdot f_H(X_H) dX_H \]
and
\[ T_{> I_{NL}^* - A_L} = \int_{I_{NL}^* - A_L}^\infty X_L \cdot f_L(X_L) dX_L \]

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