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

George Chang[1]

[1] Department of Finance, Seidman College of Business, Grand Valley State University, USA

Correspondence: George Chang, Seidman College of Business, Grand Valley State University, Grand Rapids, MI, 49504, USA. E-mail: changg@gvsu.edu

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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 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)

Model Parameters

$\%H \equiv p = 0.5$		$A_H = A_L = 10$	$I = 30$		
$X_H^u = 50,\ X_H^d = 30$		$X_L^u = 80,\ X_L^d = 0$	$\pi_u = \pi_d = 0.5$		
$E(X_H) = E(X_L) \equiv \mu = 40$		$Var(X_H) = \sigma_H^2 = 100$	$Var(X_L) = \sigma_L^2 = 160$		
Belief Set A			Belief Set B		
Don't Take:		None	Don't Take:		H (Low variance)
Take:		Both (pool)	Take:		L (High variance)
TYPE	Don't take	Take	TYPE	Don't take	Take
H	10	13.33	H	10	5
L	10	26.67	L	10	20

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 the basic Myers and Majluf model where cash flows are certain, debt would be riskless and there would be efficient investment. Brennan and Kraus (1987) shows that firms with outstanding risky debt can costlessly signal their type through financing decisions. Narayanan (1988) suggests that in a setting where the manager has private information about the mean of the distribution of the cash flows from the firm's investment opportunity but where the variance of this distribution is common knowledge, the Myers pecking order theory still apply. Noe (1988) extends Narayanan's model to a three type example, and shows that an equilibrium may obtain in which low (L) and high (H) value firms issue debt, and medium (M) value firms issue equity. 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. 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.

3. Generalization and Robustness Check

To examine the robustness of the results in Daniel and Titman (1995), we generalize the assumptions in their example by allowing for continuous-state of nature. Specifically, the random payoffs of the projects for both types firms are assumed to be normally distributed with same mean but different variances. Note that although the payoffs are assumed to be normally distributed, in all the derivations of shareholder/bondholders value, appropriate structures were imposed to make limited liability effective throughout.

We then derive the resulting closed-form solution for the equilibrium payoffs to the (original) shareholders of both types firms under different beliefs. Details of the derivation are provided in the Appendices. Table 2 presents the result using our continuous-state setting but with the same original parameters as in Daniel and Titman (1995).

Table 2. Parameters

$\%H \equiv p = 0.5$	$A_H = A_L = 10$	$I = 30$
$X_H \sim N(\mu, \sigma_H^2)$	$X_L \sim N(\mu, \sigma_L^2)$	$\mu = 40$
$\sigma_H^2 = 100$	$\sigma_L^2 = 1600$	

Note. Some parameters as in the original example, but with normally distributed project payoffs.

Belief Set A			Belief Set B		
Don't Take:	None		Don't Take:	H (Low variance)	
Take:	Both (pool)		Take:	L (High variance)	
TYPE	Don't take	Take	TYPE	Don't take	Take
H	10	11.70	H	10	3.86
L	10	22.06	L	10	15.83

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.

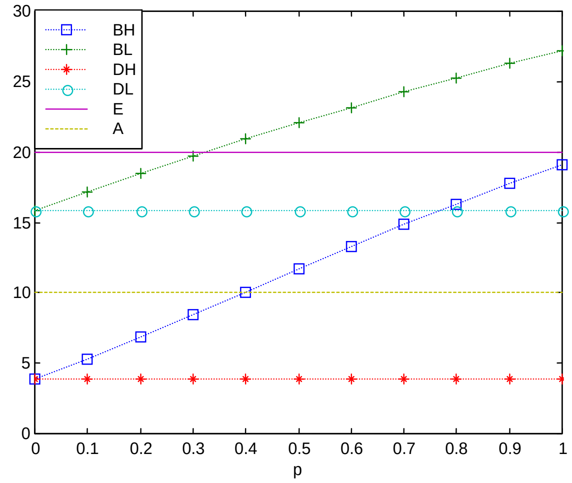

Figure 1. Sensitivity analysis with respect to probability of type-H firm

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

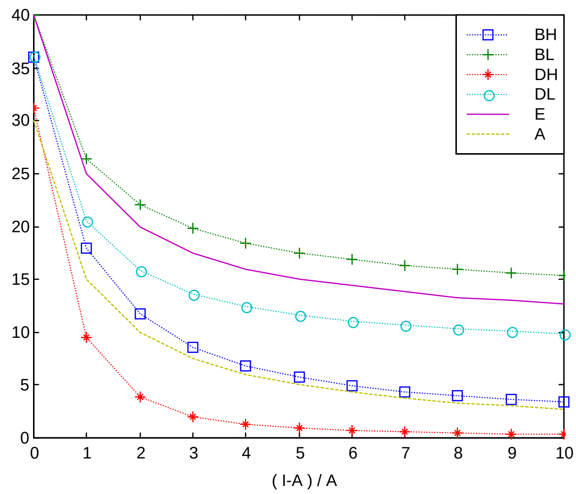

Figure 2. Sensitivity analysis with respect to (I-A)/A

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.

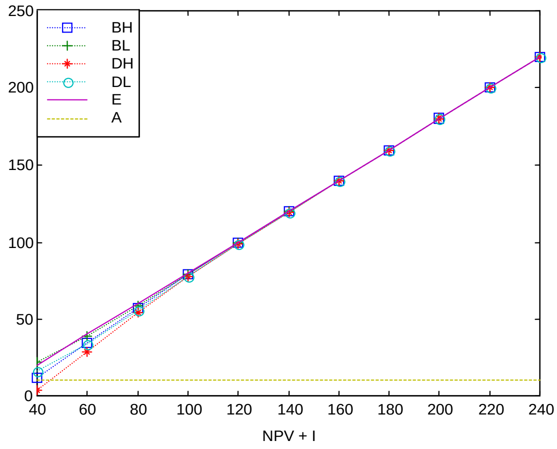

Figure 3. Sensitivity analysis with respect to NPV+ I

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

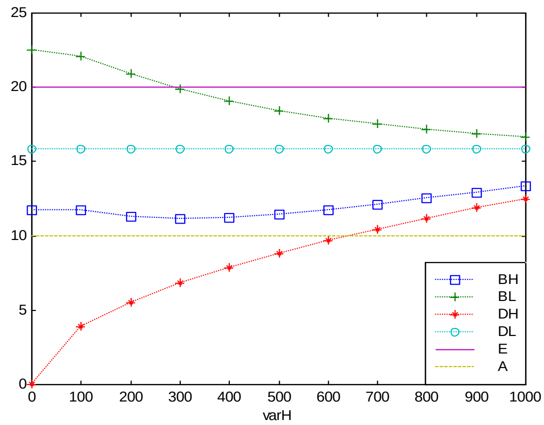

Figure 4. Sensitivity analysis with respect to varH

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

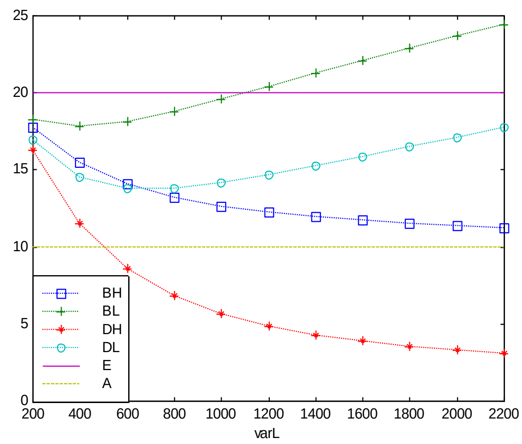

Figure 5. Sensitivity analysis with respect to varL

Note. For all values of varL, pooling equilibrium is supported. Roughly speaking, for varL>=600, separating equilibrium is supported. However, for type H firm, equity issuance dominates debt issuance.

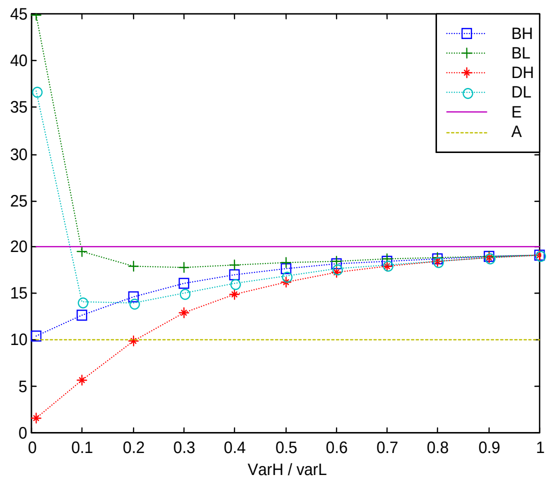

Figure 6. Sensitivity analysis with respect to varH/varL

Note. For all values of varH/varL, pooling equilibrium is supported. Roughly speaking, for varH/varL<=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

VarH= variance of firm H project's payoffs

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.

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Appendix A

Polling Notional Debt Obligation

$$
\begin{aligned}
p &= \text{prob. of H-type} \\
1-p &= \text{prob. of L-type} \\
A_H &= \text{asset-in-place of H-type} \\
A_L &= \text{asset-in-place of L-type} \\
I &= \text{project investment required} \\
NPV &= \text{expected value (net of } I \text{) of the project's cash flows}
\end{aligned}
$$

$$
\begin{aligned}
\mu &= \text{expected value of the project's gross cash flows} && \mu = NPV + I \\
X_H &= \text{random payoff of the project from H-type} && X_H \sim N\left(\mu, \sigma_H^2\right) \\
X_L &= \text{random payoff of the project from L-type} && X_L \sim N\left(\mu, \sigma_L^2\right) \qquad \sigma_H^2 < \sigma_L^2
\end{aligned}
$$

$$
\begin{aligned}
\Phi_H(\bullet) &= \text{CDF of } X_H && f_H(\bullet) = \text{PDF of } X_H \\
\Phi_L(\bullet) &= \text{CDF of } X_L && f_L(\bullet) = \text{PDF of } X_L
\end{aligned}
$$

I_{PN}^{*} = pooling notional debt obligation

I_{PN}^{*} solves

$$prob(\text{default})\cdot E[\max(X+A,0)\mid X<I-A]+prob(\text{solvent})\cdot I_{PN}^{*}=I \tag{1}$$

$$\begin{aligned}\Leftrightarrow\ & p\cdot[\Phi_H(I-A_H)\cdot E[\max(X_H+A_H,0)\mid X_H<I-A_H]]+\\ & (1-p)\cdot[\Phi_L(I-A_L)\cdot E[\max(X_L+A_L,0)\mid X_L<I-A_L]]+\\ & \{p\cdot[1-\Phi_H(I-A_H)]+(1-p)\cdot[1-\Phi_L(I-A_L)]\}\cdot I_{PN}^{*}=I\end{aligned} \tag{2}$$

Note that :

$$\begin{aligned}& E[\max(X_H+A_H,0)\mid X_H<I-A_H]\\ &=\int_{-\infty}^{\infty}\max[X_H+A_H,0]\cdot f_H(x_H\mid x_H<I-A_H)\,dx_H\\ &=\int_{-\infty}^{\infty}\max[X_H+A_H,0]\cdot\frac{f_H(x_H\ \text{and}\ x_H<I-A_H)}{\Phi_H(I-A_H)}\,dx_H\\ &=\frac{1}{\Phi_H(I-A_H)}\int_{-\infty}^{I-A_H}\max[X_H+A_H,0]\cdot f_H(x_H)\,dx_H\\ &=\frac{1}{\Phi_H(I-A_H)}\int_{-A_H}^{I-A_H}(X_H+A_H)\cdot f_H(x_H)\,dx_H\\ &=\frac{1}{\Phi_H(I-A_H)}\left\{\int_{-\infty}^{I-A_H}(X_H+A_H)\cdot f_H(x_H)\,dx_H-\int_{-\infty}^{-A_H}(X_H+A_H)\cdot f_H(x_H)\,dx_H\right\}\\ &=\frac{1}{\Phi_H(I-A_H)}\left\{\left[A_H\cdot\Phi_H(I-A_H)+T_{<I-A_H}\right]-\left[A_H\cdot\Phi_H(-A_H)+T_{<-A_H}\right]\right\}\\ &=\frac{1}{\Phi_H(I-A_H)}\left[T_{<I-A_H}-T_{<-A_H}\right]+\frac{1}{\Phi_H(I-A_H)}\left[\Phi_H(I-A_H)-\Phi_H(-A_H)\right]\cdot A_H\end{aligned} \tag{3}$$

where $T_{<I-A_H}\equiv\int_{-\infty}^{I-A_H}X_H\cdot f_H(x_H)\,dx_H \quad =\mu-\left\{\mu\cdot\left[1-\Phi_H\left(\frac{(I-A_H)-\mu}{\sigma_H}\right)\right]+\sigma_H^2\cdot f_H(I-A_H)\right\}$

is a lower truncated mean of X_H

$$\begin{aligned}T_{<-A_H}&\equiv\int_{-\infty}^{-A_H}X_H\cdot f_H(x_H)\,dx_H\\ &=\mu-\left\{\mu\cdot\left[1-\Phi_H\left(\frac{(-A_H)-\mu}{\sigma_H}\right)\right]+\sigma_H^2\cdot f_H(-A_H)\right\}\end{aligned}$$

is a lower truncated mean of X_L

Similarly,

$$E[\max(X_L+A_L,0)\mid X_L<I-A_L]=\frac{1}{\Phi_L(I-A_L)}\left[T_{<I-A_{L_L}}-T_{<-A_L}\right]+\frac{1}{\Phi_L(I-A_L)}\left[\Phi_L(I-A_L)-\Phi_L(-A_L)\right]\cdot A_L \tag{4}$$

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

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

$$Q_L=\left[T_{<I-A_L}-T_{<-A_L}\right]+\left[\Phi_L(I-A_L)-\Phi_L(-A_L)\right]\cdot A_L$$

We have

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

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

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

$$\begin{aligned}
B_H &= E\left[\max\left(A_H + X_H - I^*_{PN},\ 0\right)\right] \\
&= \int_{-\infty}^{\infty} \left[\max\left(A_H + X_H - I^*_{PN},\ 0\right)\right] \cdot f_H(X_H)\, dX_H \\
&= \int_{I^*_{PN} - A_H}^{\infty} \left(A_H + X_H - I^*_{PN}\right) \cdot f_H(X_H)\, dX_H \\
&= \int_{I^*_{PN} - A_H}^{\infty} \left(A_H - I^*_{PN}\right) \cdot f_H(X_H)\, dX_H + \int_{I^*_{PN} - A_H}^{\infty} X_H \cdot f_H(X_H)\, dX_H \\
&= \left[1 - \Phi_H\left(I^*_{PN} - A_H\right)\right] \cdot \left(A_H - I^*_{PN}\right) + T_{>I^*_{PN} - A_H}
\end{aligned} \tag{6}$$

where
$$\begin{aligned}
T_{>I^*_{PN} - A_H} &= \int_{I^*_{PN} - A_H}^{\infty} X_H \cdot f_H(X_H)\, dX_H \\
&= \mu \cdot \left[1 - \Phi_H\left(\frac{\left(I^*_{PN} - A_H\right) - \mu}{\sigma_H}\right)\right] + \sigma_H^2 \cdot f_H\left(I^*_{PN} - A_H\right)
\end{aligned}$$

Similarly,

$$\begin{aligned}
B_L &= E\left[\max\left(A_L + X_L - I^*_{PN},\ 0\right)\right] \\
&= \left[1 - \Phi_L\left(I^*_{PN} - A_L\right)\right] \cdot \left(A_L - I^*_{PN}\right) + T_{>I^*_{PN} - A_L}
\end{aligned} \tag{7}$$

where
$$\begin{aligned}
T_{>I^*_{PN} - A_L} &= \int_{I^*_{PN} - A_L}^{\infty} X_L \cdot f_L(X_L)\, dX_L \\
&= \mu \cdot \left[1 - \Phi_L\left(\frac{\left(I^*_{PN} - A_L\right) - \mu}{\sigma_L}\right)\right] + \sigma_L^2 \cdot f_L\left(I^*_{PN} - A_L\right)
\end{aligned}$$

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-type firm's (old) shareholders' expected value under Belief Set B

D_L = L-type firm's (old) shareholders' expected value under Belief Set B

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

Hence,

$$I_{NL}^{*} = \frac{I - Q_L}{1 - \Phi_L\left(I - A_L\right)} \tag{8}$$

By the same derivations as in (6) and (7), we have

$$D_H = E\left[\max\left(A_H + X_H - I_{NL}^{*}\ ,\ 0\right)\right] = \left[1 - \Phi_{\mathrm{H}}\left(I_{NL}^{*} - A_H\right)\right] \cdot \left(A_H - I_{NL}^{*}\right) + T_{>I_{NL}^{*} - A_H} \tag{9}$$

And

$$D_L = E\left[\max\left(A_L + X_L - I_{NL}^{*}\ ,\ 0\right)\right] = \left[1 - \Phi_{\mathrm{L}}\left(I_{NL}^{*} - A_L\right)\right] \cdot \left(A_L - I_{NL}^{*}\right) + T_{>I_{NL}^{*} - A_L} \tag{10}$$

where $T_{>I_{NL}^{*} - A_H} = \int_{I_{NL}^{*} - A_H}^{\infty} X_H \cdot f_H\left(X_H\right) dX_H$

and $T_{>I_{NL}^{*} - A_L} = \int_{I_{NL}^{*} - A_L}^{\infty} X_L \cdot f_L\left(X_L\right) dX_L$