Optimal Capital Structure and Industry Dynamics

JIANJUN MIAO[1]

September 2003

[1]Department of Economics, Boston University, 270 Bay State Road, Boston, MA 02215. Email: miaoj@bu.edu. Phone: (617) 353-6675. I thank Larry Epstein and Erwan Morellec for constant support and advice. I also thank seminar participants at many institutions, especially, Rui Albuquerque, Mike Barclay, Dan Bernhardt, Pierre Collin-Dufresne, Ludger Hentschel, Burton Hollifield, Hugo Hopenhayn, Larry Kotlikoff, Hayne Leland, John Long, Josef Perktold, Victor Rios-Rull, and Sheridan Titman for helpful comments. The paper is perviously titled: "Optimal Capital Structure and Industry Dynamics in Stationary Equilibrium". First version: June 2002. The latest version can be downloaded from: http://people.bu.edu/miaoj.

Abstract

This paper presents an equilibrium model of industry dynamics and capital structure decisions. The unique stationary equilibrium is derived in closed-form. The analysis reveals that the interaction between capital structure and production decisions influences the stationary distribution of surviving firms and their survival probabilities. Under reasonably calibrated parameter values, the model predicts a low average industry leverage ratio which is in line with that observed in practice. Comparative static analysis demonstrates that the model can generate the relation between capital structure and firms' entry, exit and production decisions documented in the evidence. The model also provides a number of new predictions regarding industry dynamics and capital structure.

Keywords: capital structure, agency costs, entry, exit, equilibrium interaction, firm turnover, stationary equilibrium
JEL Classification Numbers: G32, G33, G12

1 Introduction

1.1 Motivation and Outline

The interaction between capital structure and product market decisions has recently received considerable attention in both economics and finance. Beginning with Brander and Lewis (1986, 1988) and Maksimovic (1988), a growing number of theoretical papers investigate this interaction. In addition, many empirical studies (Chevalier (1995a, 1995b), Phillips (1995), Kovenock and Phillips (1997), Maksimovic and Phillips (1998), Zingales (1998), Lang *et al* (1996), Mackay and Phillips (2001)) examine the relation between capital structure and firm entry, exit, investment and output decisions.[1] These studies generally document the following:

- Industry output is negatively associated with the average industry debt ratio.
- Plant closing is positively associated with debt and negatively associated with plant-level productivity.
- Firm entry is positively associated with debt of incumbents.
- Investment is negatively associated with debt.
- There is substantial within- and across-industry variation in leverage.

It is well known that debt causes the underinvestment and asset substitution problems identified by Myers (1977) and Jensen and Meckling (1976). However, it is important to emphasize that simply taking leverage as an exogenous regressor may be misleading. This is because rational firms may anticipate the effect of leverage on product/input market behavior so that the latter may influence capital structure choices. This endogeneity has been recognized; in particular, Zingales (1998, p. 905) points out that "in the absence of a structural model we cannot determine whether it is the product market competition that affects capital structure choices or a firm's capital structure that affects its competitive position and its survival". This endogeneity problem makes the interpretation of the above empirical evidence controversial.

The main contribution of my paper is to fill this theoretical gap by providing an industry equilibrium model in which capital structure choices and production decisions are simultaneously influenced by the same exogenous factors.

[1]Early studies that relate the cross-sectional behavior of leverage to industry characteristics include Bradley et al (1984) and Titman and Wessels (1988) among others.

Another contribution of my paper is related to industrial organization. Many empirical studies in industrial organization have documented cross-industry differences in firm turnover. However, little theoretical research has been devoted to understanding the impact of financing policies on firm turnover.[2] The second contribution of this paper is to show how the interaction between financing and production decisions influences firm turnover and to provide new testable predictions regarding the determinants of firm turnover.

I now outline the basic structure of the model. The model features a continuum of firms facing idiosyncratic technology shocks. These firms are controlled by shareholders and make financing, entry, exit and production decisions. The capital structure choice is modelled by incorporating approaches of Modigliani and Miller (1958, 1963), Kraus and Litzenberger (1973), and Jensen and Meckling (1976).[3] Moreover, this choice reflects the equilibrium interaction between financing and production/investment decisions. Specifically, production/investment decisions are chosen to maximize equity value after debt is in place so that shareholder-bondholder conflicts lead to agency costs as in Jensen and Meckling (1976) and Myers (1977).[4] The initial capital structure choice, made ex ante, trades off the tax advantage of debt versus bankruptcy costs plus agency costs. Thus the model departs from the standard Modigliani-Miller framework.

In a long-run *stationary industry equilibrium*, there is a stationary distribution of surviving firms. These firms exhibit a wide variation of leverage. Furthermore, all industry-wide equilibrium variables are constant over time, although individual firms are continually adjusting, with some of them expanding, others contracting, some starting up, and others closing down.

I derive a closed-form solution for the unique stationary equilibrium so that the model can be analyzed tractably. I also study the effects on the equilibrium of changes in growth of technology, risks of technology, entry distribution, fixed operating cost, entry cost, bankruptcy cost, and corporate tax.

I now highlight the main mechanism operating in the model by an example. Consider the effect of an increase in technology growth and a risk neutral environment. First, this increase has a *cash flow effect* in the sense that operating profits are higher. It also has an

[2]See Caves (1998) for a survey of the empirical literature on firm turnover. See Jovanovic (1982), Hopenhayn (1992), and Ericson and Pakes (1995) for important theoretical models of industry dynamics. All these papers assume that firms are all equity financed.

[3]See Harris and Raviv (1991) for a survey of the theory of capital structure. They point out that 'with regard to further theoretical work, it appears that models relating to products and inputs are underexplored, while the asymmetric information approach has reached the point of diminishing returns' (pp. 299-300).

[4]I do not consider conflicts between shareholders and managers. Morellec (2002) examines these conflicts in a contingent claim framework.

option effect in the sense that it changes the expected appreciation in the value of the option to default. These two effects raise firm value and the benefit of remaining active. Thus, the firm is less likely to default, and has lower expected bankruptcy costs. The standard single firm tradeoff theory then predicts that the firm should issue more debt. However, the prediction that high-growth firms have high leverage is refuted by many empirical studies (see Rajan and Zingales (1995), Barclay et al (2002), and references cited therein).

In the present industry equilibrium model, there is an important *price feedback effect* associated with an increase in technology growth. That is, potential entrants will anticipate increased firm value and hence prefer to enter the industry. As a result, product market competition causes the output price to fall. The decreased output price influences the firm's financing and liquidation/exit decisions. In particular, in contrast to standard single-firm tradeoff models, this feedback effect may dominate so as to raise exit probabilities, lower coupon payments, and lower the average industry leverage ratio.

The model also has important implications for industry dynamics. Specifically, an increase in the rate of technology growth and the induced increase in exit probabilities have a *selection effect* in that the stationary distribution of surviving firms changes. This selection effect causes inefficient firms to exit and be replaced by new entrants, leading to higher industry output and a lower turnover rate.

Another important implication of the present model is that, in the presence of corporate income taxes, debt financing raises firm value, turnover rate, and industry output, compared to Hopenhayn's (1992) model without debt financing.

1.2 Related Literature

There are three strands of related literature. One strand beginning with Black and Scholes (1973) and Merton (1974) is in the framework of dynamic contingent claims analysis. Brennan and Schwartz (1984), Mello and Parsons (1992), Mauer and Triantis (1994), and Titman and Tsyplakov (2002) analyze the interaction between investment and financing decisions using numerical methods. Dixit (1989) studies entry and exit decisions under all equity financing. Leland (1994, 1998), Leland and Toft (1996), Goldstein et al. (2001), and Morellec (2001) analyze corporate asset valuation and optimal capital structure using analytical methods. All these models consider a single firm environment. Under perfect competition, Leahy (1993) analyzes entry and exit under all equity financing in an industry equilibrium framework. Fries, Miller, and Perraudin (1997) generalize Leahy's model and study how entry and exit affect corporate asset valuation and capital structure.[5] Lambrecht

[5]Maksimovic and Zechner (1991) present a three-period industry equilibrium model where firms can adopt different technologies. They do not study entry and exit decisions. See Williams (1995) for an extension in

(2001) analyzes the impact of debt financing on entry and exit in an oligopoly environment.

Another strand is based on the framework developed by Hopenhayn (1992a, 1992b) and Hopenhayn and Rogerson (1993) where the concept of stationary equilibrium is introduced to analyze industry dynamics. Most papers in this strand assume firms are all equity financed. Cooley and Quadrini (2001) introduce capital structure decisions into this framework and study how financial frictions account for the negative dependence of firm dynamics (growth, job reallocation, and exit) on size and age. They assume exogenous exit and consider standard one-period debt contracts based on asymmetric information. Their analysis relies mainly on numerical method.

The third strand of literature is based on strategic models. Some papers in this strand (Brander and Lewis (1986, 1988) and Maksimovic (1988)) argue that product market competition becomes 'tougher' when leverage increases, while others (e.g., Poitevin (1989), Bolton and Scharfstein (1990), and Dasgupta and Titman (1998)) reach the opposite conclusion. Since most models in this strand are essentially static, it seems that they are not suitable to address the questions of industry dynamics and corporate asset valuation.

My model combines elements of the first two strands of literature. In particular, I incorporate capital structure decisions into the framework of Hopenhayn (1992a) using the contingent claims analysis. This allows me to derive a number of new predictions regarding the relation between leverage and firm turnover. My model is also closely related to Fries et al (1997) and Lambrecht (2001). Unlike Lambrecht (2001), I study perfectly competitive industries. In addition, different from these two papers where uncertainty comes from aggregate industry demand shocks, I assume that firms face idiosyncratic technology shocks as in Hopenhayn (1992a). The basic intuition behind the difference between firm-specific shocks and industry-wide shocks is explained in Dixit and Pindyck (1994, Chapter 8).

The remainder of the paper is organized as follows. Section 2 sets up the model. Section 3 studies a single firm's optimal capital structure choice in an industry setting. Section 4 derives closed-form solutions for the unique equilibrium. Section 5 analyzes properties of the equilibrium. Section 6 extends the model to allow for debt reorganization through debt exchange offers. Section 7 concludes. Technical details are relegated to an appendix.

2 The Model

Consider an industry consisting of a large number of firms. Suppose that information is perfect and that all investors are risk neutral and discount future cash flows at a constant risk-free rate $r > 0$. The assumption of risk neutrality does not lose any generality. If agents

a four-period model.

are risk averse, the analysis may be conducted under the risk neutral measure (see Harrison and Kreps (1979)).

Time is continuous and varies over $[0, \infty)$. Uncertainty is represented by a probability space $(\Omega, \mathcal{F}, \mathbb{P})$ on which all stochastic processes are defined. The objective is to study long-run stationary industry equilibria in which all industry-wide aggregate variables are constant (see Section 2.4 for a formal definition). In particular, the equilibrium output price is constant, and there is an equilibrium stationary distribution of surviving firms.

2.1 Industry Demand

Industry demand is given by a decreasing function. For simplicity, I take the following iso-elastic functional form:

$$p = Y^{-\frac{1}{\varepsilon}}, \tag{1}$$

where p is the output price, Y is the industry output, and $\varepsilon > 0$ is the price elasticity of demand.

2.2 Firms

There is a continuum of firms. At each date, each firm suffers independently exogenous death under the Poisson process with parameter $\eta > 0$. This assumption captures the fact that some firms exit the industry for reasons that are not related to bankruptcy. In addition, it is important to ensure the existence of a stationary distribution of firms studied later since the technology shock is a nonstationary process, as I describe next.

Technology Each firm rents capital at the rental rate R to produce output with the production function $F : \mathbb{R}_+ \to \mathbb{R}_+$, $F(k) = k^\nu$, where $\nu \in (0, 1)$. The decreasing-returns-to-scale assumption ensures that the firm's profit is positive so that the decision problem of entry and exit studied below is meaningful. Capital depreciates continuously at a constant rate $\delta > 0$. Thus the rental rate R is equal to $r + \delta$.

Firms are ex ante identical in that their technology or productivity shocks are drawn from the same distribution. They differ ex post in the realization of idiosyncratic shocks. Suppose that there is no aggregate uncertainty and a law of large numbers for a continuum of random variables so that industry aggregates are constant (see Judd (1985), Feldman and Gilles (1985), and Miao (2002)).

For an individual firm, the technology shock process $(z_t)_{t\geq 0}$ is governed by a geometric Brownian motion:

$$dz_t/z_t = \mu_z dt + \sigma_z dW_t, \tag{2}$$

where μ_z and σ_z are positive constants. Here $(W_t)_{t\geq 0}$ is a standard Brownian motion representing firm-specific uncertainty.

Profit Function At each time each firm incurs a fixed operating cost $c_f > 0$ to produce output. Corporate income is taxed at the rate τ with full loss-offset provisions.[6] Define the after-tax profit function Ψ by

$$\Psi(z;p) = \max_{k\geq 0}(1-\tau)\left(pzF(k) - \delta k - c_f\right) - rk. \tag{3}$$

Notice that, according to the US tax system, the depreciation of capital is tax-deductible, but the interest cost of capital is not. Profit maximization implies the following neoclassical investment rule:

$$pzF'(k) = r/\left(1-\tau\right) + \delta. \tag{4}$$

That is, the marginal product of capital is equal to the tax-adjusted user cost of capital. Using this equation, one can solve for the capital demand and output supply

$$k(z;p) = z^{\gamma}\left(\frac{p\nu}{r/(1-\tau)+\delta}\right)^{\gamma},\ y(z;p) = zF(k(z;p)) = z^{\gamma}\left(\frac{p\nu}{r/(1-\tau)+\delta}\right)^{\nu\gamma}. \tag{5}$$

where $\gamma \equiv \frac{1}{1-\nu}$. Substituting the above equation into (3) yields the after-tax profit function

$$\Psi(z;p) = (1-\tau)\left[a(p)z^{\gamma} - c_f\right],$$

where

$$a(p) \equiv p^{\gamma}(1-\nu)\left(\frac{\nu}{r/(1-\tau)+\delta}\right)^{\nu\gamma}. \tag{6}$$

The before-tax profit function is defined as

$$\pi(z;p) \equiv a(p)z^{\gamma} - c_f. \tag{7}$$

[6] I abstract from personal taxes in the paper.

Debt Contracts Because interest payments to debt are tax deductible, each firm has an incentive to issue debt. In order to obtain a closed-form solution, I consider a time-homogenous environment where debt contracts have infinite maturity, as in Leland (1994). Debt is issued at par. The debt contract specifies a perpetual flow of coupon payments b to bondholders. The remaining cash flows from operation accrue to shareholders. If the firm defaults on its debt obligations, it is immediately liquidated. Upon default, bondholders get the liquidation value and shareholders get nothing.

Liquidation Value Suppose that debt reorganization is so costly that after default the firm is immediately liquidated and exits the industry. Section 6 will relax this assumption and consider debt reorganization. I model liquidation value as a fraction $\alpha \in (0,1)$ of the unlevered firm value $A(z;p)$. The remaining fraction accounts for bankruptcy costs. One can model liquidation value as a general function of the output price $X(p)$ as in Fries et al (1997). Here, I follow Mello and Parsons (1992). Unlevered firm value is equal to the after-tax present value of profits, plus the option value associated with abandonment opportunities. Normalize the abandonment value of the firm to zero. Then, unlevered firm value can be formally described by

$$A(z;p) = (1-\tau) \sup_{T \in \mathcal{T}} E^z \left[\int_0^T e^{-(r+\eta)t} \pi(z_t;p) dt \right], \tag{8}$$

where the maximization is over the set $\mathcal{T}$ of all stopping times relative to the filtration generated by the Brownian motion $(W_t)_{t \geq 0}$, E^z is the expectation operator for the process $(z_t)_{t \geq 0}$ starting at z, and the factor $e^{-\eta t}$ accounts for the possibility of Poisson death.

Investment and Liquidation Decisions At each date t, after servicing coupon payments b, residual cash flows $(1-\tau)(pz_tF(k_t) - \delta k_t - c_f - b) - rk_t$ are distributed to shareholders as dividends. Shareholders select the investment and default policy to maximize the value of their claims. Assume that default is triggered by the decision of shareholders to cease raising additional equity to meet the coupon payment, as in Mello and Parsons (1992), Leland (1994), Fries et al (1997), Lambrecht (2001), and Duffie and Lando (2001).

The investment and liquidation decisions made by a typical firm with the current level of technology shock z and coupon payment b are described by the following problem:

$$e(z,b;p) = \sup_{k_t \geq 0, T \in \mathcal{T}} E^z \left\{ \int_0^T e^{-(r+\eta)t} \left[(1-\tau)(pz_tF(k_t) - \delta k_t - c_f - b) - rk_t \right] dt \right\}. \tag{9}$$

This problem can be rewritten as

$$e(z,b;p)=\sup_{T\in\mathcal{T}}(1-\tau)E^z\left[\int_0^T e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right],$$

where $\pi(z_t;p)$ is given in (7). The expression $e(z,b;p)$ represents the equity value of the firm. Since one can show that it is increasing in z, the default decision is described by a trigger policy whereby the firm is immediately liquidated and exits the industry once its technology shock $(z_t)_{t\geq 0}$ falls below an endogenously determined threshold $z_d(b;p)$ (see Duffie and Lando (2001)). In what follows, without risk of confusion, I may simply use z_d to denote $z_d(b;p)$.

The equity-value-maximizing investment policy is described by the neoclassical rule (4), with the difference being that investment takes place only in the no default region $z>z_d(b;p)$. This is related to the underinvestment problem of debt pointed out by Myers (1977).

Notice that the limited liability feature of equity is embodied in problem (9) since equity value is always positive before default ($z>z_d(b;p)$), and is zero only upon default ($z=z_d(b;p)$).

Debt Value and Firm Value The arbitrage-free value of debt is equal to the sum of the present value of coupon payments accruing to bondholders until the default time and the present value of liquidation value upon default. That is, debt value $d(z,b;p)$ is given by

$$d(z,b;p)=E^z\left[\int_0^{T_{z_d}} e^{-(r+\eta)t}bdt\right]+\alpha A(z_d;p)E^z\left[e^{-(r+\eta)T_{z_d}}\right], \tag{10}$$

where T_y denotes the first time that the process $(z_t)_{t\geq 0}$ falls to some boundary value $y>0$. Firm value $v(z,b;p)$ is the sum of equity value and debt value,

$$v(z,b;p)=e(z,b;p)+d(z,b;p).$$

Entry At each date there is a continuum of potential entrants. Entry incurs a fixed sunk cost c_e. This cost can be financed by equity and debt. After entry, a firm's initial level of technology z is drawn from the distribution ζ, which is uniform over $[\underline{z},\overline{z}]$. This firm is then in the same position as an incumbent with the initial level of technology z. The uniform entry distribution is important to derive a closed-form solution for the stationary distribution of incumbents.

Assume that $\underline{z}>z_d(b;p)$. Since z_d is endogenous, this assumption must be verified in equilibrium. I rule out the case in which the initial draw of technology shock is below the default threshold so that the entrant is immediately liquidated and exits the industry.

Before entry, firms are identical and do not know their initial technology levels and subsequent random evolution of technology. Thus, in a competitive equilibrium, if there is positive entry, then the expected benefit of entry must be equal to the entry cost. That is, the following entry condition must hold,

$$\int_{\underline{z}}^{\overline{z}} v(z, b; p)\zeta(dz) = c_e. \tag{11}$$

Finally, upon entry firms may adjust the capital structure in order to balance the benefit and cost of debt. The optimal coupon rate $b^*(p)$ is chosen to maximize the expected value of the firm $\int_{\underline{z}}^{\overline{z}} v(z, b; p)\zeta(dz)$. Since all firms are ex ante identical, they choose the same optimal coupon rate. For tractability, I assume that transactions costs are so high that firms do not re-adjust debt after entry. Section 6 will discuss this further.

Time-line for Decisions In summary, the sequence of events and the timing of decisions for a typical firm are described in Figure 1.

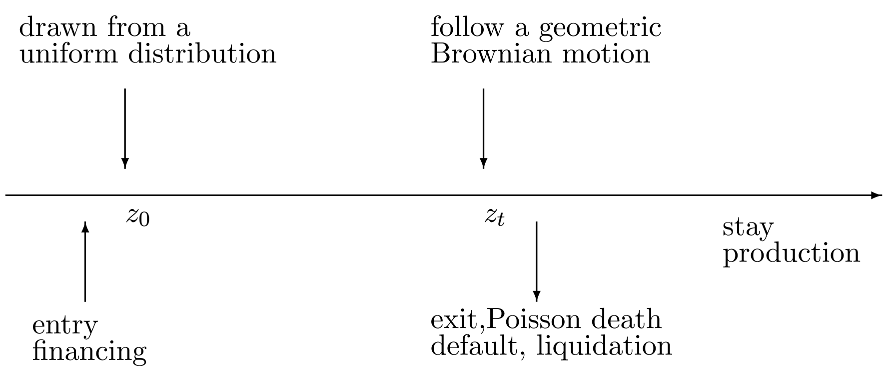

Figure 1: **Time-line for decisions**

2.3 Aggregation

In a stationary equilibrium, there is a stationary distribution of surviving firms μ and a constant entry rate N.[7] Note that the distribution μ is not a probability measure. For any

[7]The entry (exit) rate is defined as the number of firms entering (going bankrupt and exiting) the industry at each time. The same term used in some empirical studies (e.g. Dunne et al (1988)) corresponds to the turnover rate defined later.

Borel set $\mathcal{B}$ in the real line, $\mu(\mathcal{B})$ describes the mass of surviving firms with shocks in $\mathcal{B}$. Since the firm exits when its technology shock falls below $z_d(b;p)$, the support of μ is the interval $[z_d, \infty)$. Using this stationary distribution, one can determine aggregate capital

$$K(\mu, b; p) = \int_{z_d(b;p)}^{\infty} k(z;p)\mu(dz), \tag{12}$$

and aggregate output

$$Y(\mu, b; p) = \int_{z_d(b;p)}^{\infty} y(z;p)\mu(dz), \tag{13}$$

where $k(z;p)$ and $y(z;p)$ are given in (5).

2.4 Equilibrium

A *stationary industry equilibrium with exogenous leverage,* (p^*, z_e, N^*, μ^*), consists of a constant output price p^*, an exit threshold $z_e = z_d(b; p^*)$, an entry rate N^*, and a distribution of incumbents μ^* such that: (i) Firms solve problem (9). (ii) The market clear:

$$p^* = Y(\mu^*, b; p^*)^{-1/\varepsilon}. \tag{14}$$

where $Y(\cdot)$ is given in (13). (iii) The entry condition (11) holds. (iv) The distributions μ^* is an invariant measure over $[z_e, \infty)$, i.e., for any Borel set $\mathcal{B}$ on $[z_e, \infty)$ and all $t > 0$,

$$\mu^*(\mathcal{B}) = \int_{z_e}^{\infty} e^{-\eta t} Q(t, x, \mathcal{B})\mu^*(dx) + N^* \int_{z_e}^{\infty} \mathbf{1}_{[\underline{z}, \overline{z}]\cap\mathcal{B}}(y)\zeta(dy), \tag{15}$$

where $\mathbf{1}$ is an indicator function and $Q(t, \cdot, \cdot)$ is the transition function of the process $(z_t)_{t\geq 0}$. Note that equation (15) defines the stationary measure of incumbents, which is similar to the discrete-time analog in Hopenhayn (1992a).

In this equilibrium, the coupon rate b is exogenously given. When b is chosen to maximize firm value, the resulting equilibrium is called the *stationary equilibrium with endogenous leverage*. Such an equilibrium is denoted by $(p^o,\, z_e^o, N^o, \mu^o)$.

It is important to point out that the exit threshold determines not only a firm's liquidation/exit decisions, but also the minimum efficiency level of surviving firms.

3 Optimal Capital Structure

In this section, I fix the output price p and consider a single firm's capital structure decision. This decision is modelled in the spirit of the standard EBIT-based single-firm contingent-claim models, such as Mello and Parsons (1992) and Goldstein et al (2001). However, different from these models, investment policies are not fixed and the product market influences the capital structure decision through the output price.

3.1 Unlevered Firm Value

I begin by deriving unlevered firm value. Because unlevered firm value is increasing in z, the solution to (8) is described by a threshold value z_A. The firm is abandoned the first time when the technology shock falls below z_A. To solve for this threshold value z_A and unlevered firm value, let

$$A(z;p|y) = (1-\tau)E^z\left[\int_0^{T_y} e^{-(r+\eta)t}\pi(z_t;p)dt\right],$$

be unlevered firm value given any threshold level $y > 0$. Here T_y denotes the first passage time of the process $(z_t)_{t\geq 0}$ starting from z to y.

Let $\Pi(z;p)$ denote the before-tax present value of the profit flow

$$\Pi(z;p) \equiv E^z\left[\int_0^{\infty} e^{-(r+\eta)t}\pi(z_t;p)dt\right].$$

Using (7), one can show that

$$\Pi(z;p) = \frac{a(p)}{\lambda}z^\gamma - \frac{c_f}{r+\eta} \tag{16}$$

where $a(p)$ is given by (6) and

$$\lambda \equiv r + \eta - \mu_z\gamma - \sigma_z^2\gamma(\gamma-1)/2. \tag{17}$$

To ensure that $\Pi(z;p)$ is finite, I assume $\lambda > 0$.

In the appendix, I show that

$$A(z;p|y) = (1-\tau)\Pi(z;p) - (1-\tau)\Pi(y;p)\left(\frac{z}{y}\right)^\vartheta, \tag{18}$$

where

$$\vartheta = \frac{1}{\sigma_z^2}\left[(\sigma_z^2/2 - \mu_z) - \sqrt{2(r+\eta)\sigma_z^2 + (\sigma_z^2/2-\mu_z)^2}\right] < 0. \tag{19}$$

The abandonment threshold z_A is determined by the smooth-pasting condition

$$\left.\frac{\partial A(z;p|z_A)}{\partial z}\right|_{z=z_A} = 0.$$

Solving this equation yields

$$z_A = \left[\frac{\vartheta\lambda c_f}{(\vartheta-\gamma)(r+\eta)a(p)}\right]^{1/\gamma}. \tag{20}$$

Thus, unlevered firm value is given by

$$A(z;p) = (1-\tau)\Pi(z;p) - (1-\tau)\Pi(z_A;p)\left(\frac{z}{z_A}\right)^\vartheta, \; z \geq z_A. \tag{21}$$

The second term represents the option value of abandonment.

3.2 Liquidation Decision and Equity Value

Recall that the firm's liquidation decision is described by a trigger policy. To solve for equity value and the optimal default threshold z_d, let

$$e(z, b; p|y) = (1 - \tau)E^z \left[\int_0^{T_y} e^{-(r+\eta)t}(\pi(z_t; p) - b)dt \right]$$

denote the equity value when the default threshold is given by y and the coupon rate is given by b. In the appendix, I show that

$$e(z, b; p|y) = (1 - \tau) \left(\Pi(z; p) - \frac{b}{r + \eta} \right) - (1 - \tau) \left(\Pi(y; p) - \frac{b}{r + \eta} \right) \left(\frac{z}{y} \right)^{\vartheta}, \qquad (22)$$

Since shareholders may always cover operating losses by raising additional equity, they choose a default threshold y so as to maximize equity value $e(z, b; p|y)$. The optimal default threshold z_d satisfies the smooth-pasting condition

$$\left. \frac{\partial e(z, b; p|z_d)}{\partial z} \right|_{z=z_d} = 0.$$

Solving yields

$$z_d(b; p) = \left[\frac{\vartheta\lambda(b + c_f)}{(\vartheta - \gamma)(r + \eta)a(p)} \right]^{1/\gamma}. \qquad (23)$$

This equation implies

$$\Pi(z_d; p) = \frac{\vartheta}{\vartheta - \gamma} \frac{b}{r + \eta}. \qquad (24)$$

Thus, the optimal liquidation policy for shareholders consists in liquidating when the present value of the profit flow upon default $\Pi(z_d; p)$ is equal to the cost of servicing debt $b/(r + \eta)$ multiplied by the factor $\vartheta/(\vartheta - \gamma) \in (0, 1)$ that represents an option value of waiting to default. It is important to note that unlike single-firm models, product market behavior affects the liquidation decision because the output price affects the present value of the profit flow.

Equation (23) also implies that the liquidation threshold $z_d(b; p)$ is increasing in b and decreasing in p (note that $a(p)$ is increasing in p). Thus, higher debt or lower output price causes the firm to exit earlier. Higher debt also induces underinvestment as in Myers (1977) in the sense that the range of the states over which investment takes place is smaller.

Finally, substituting z_d for y into equation (22) yields the equity value of the firm:

$$e(z, b; p) = (1 - \tau) \left[\Pi(z; p) - \frac{b}{r + \eta} + \left(\frac{b}{r + \eta} - \Pi(z_d; p) \right) \left(\frac{z}{z_d} \right)^{\vartheta} \right], \; z \geq z_d. \qquad (25)$$

Thus, equity value is equal to the after-tax value of the present value of the profit flow, minus the present value of coupon payments, plus the option value of default.

3.3 Debt Value and Firm Value

Applying a similar method used to derive (22), debt value in (10) can be solved as

$$d(z, b; p) = \frac{b}{r+\eta} + \left(\alpha A(z_d; p) - \frac{b}{r+\eta}\right)\left(\frac{z}{z_d}\right)^{\vartheta}, \ z \geq z_d. \tag{26}$$

Thus, debt value is equal to the present value of coupon payments, plus the probability-adjusted changes in value if and when default occurs. Note that, under the present specification of liquidation value, one can show that $\alpha A(z_d; p) < \frac{b}{r+\eta}$ so that debt is risky, i.e., $d(z, b; p) < \frac{b}{r+\eta}$.

Firm value is equal to the sum of equity value and debt value. Thus, by (25) and (26),

$$v(z, b; p) = e(z, b; p) + d(z, b; p) =$$

$$A(z; p) + \frac{b\tau}{r+\eta}\left[1 - \left(\frac{z}{z_d}\right)^{\vartheta}\right] - (1-\alpha)A(z_d; p)\left(\frac{z}{z_d}\right)^{\vartheta}, \tag{27}$$

for $z \geq z_d$. This implies that levered firm value equals unlevered firm value plus the probability-adjusted tax shield of debt minus probability-adjusted bankruptcy costs.

3.4 Optimal Coupon

Upon entry, the firm adjusts its capital structure to balance the benefit and cost of debt. Thus, it chooses an optimal coupon rate b^* to maximize its expected value; that is

$$b^*(p) \in \arg\max_b \int_{\underline{z}}^{\overline{z}} v(z, b; p)\zeta(dz). \tag{28}$$

Since it can be shown that v is strictly concave in b, the following first-order condition determines the optimal coupon rate

$$\frac{\tau}{r+\eta}\left[1 - \int_{\underline{z}}^{\overline{z}}\left(\frac{z}{z_d}\right)^{\vartheta}\zeta(dz)\right] = \frac{-\vartheta}{\gamma}\frac{\tau b}{(r+\eta)(b+c_f)}\int_{\underline{z}}^{\overline{z}}\left(\frac{z}{z_d}\right)^{\vartheta}\zeta(dz) \tag{29}$$

$$+\frac{1-\alpha}{\gamma(b+c_f)}\left[A'(z_d; p)z_d - \vartheta A(z_d; p)\right]\int_{\underline{z}}^{\overline{z}}\left(\frac{z}{z_d}\right)^{\vartheta}\zeta(dz),$$

where the liquidation threshold z_d is given by (23) and

$$E_\zeta\left[z^\vartheta\right] = \int_{\underline{z}}^{\overline{z}} z^\vartheta \zeta(dz) = \frac{\overline{z}^{\vartheta+1} - \underline{z}^{\vartheta+1}}{(\vartheta+1)(\overline{z}-\underline{z})}.$$

The expression on the left side of equation (29) represents the probability-adjusted marginal tax advantage of debt and the expression on the right side represents the marginal bankruptcy cost. In particular, the first term on the right side represents the loss of marginal tax shield due to bankruptcy. The second term on the right side represents the loss of marginal liquidation value due to an inefficient choice of liquidation time by the shareholder. The optimal capital structure prescribes a coupon rate so that the marginal benefit of debt equals the marginal cost.

Unlike single-firm models, the present model implies that product market competition influences the firm's financing decisions since industry output price affects the optimal coupon rate. This is transparent when there is no fixed operating cost ($c_f = 0$). In this case, there is a closed form solution to (29):

$$b^*(p) = \frac{(\vartheta-\gamma)(r+\eta)a(p)}{\vartheta\lambda}\left[\frac{\gamma-\vartheta}{\gamma} - \frac{\vartheta(1-\alpha)(1-\tau)}{\gamma\tau}\right]^{\frac{\gamma}{\vartheta}} E_\zeta\left[z^\vartheta\right]^{\frac{\gamma}{\vartheta}}. \tag{30}$$

This equation implies that the optimal coupon is increasing in the output price p. The intuition is that, when the output price p is higher, the firm is less likely to default so that it prefers to issue more debt.

3.5 Agency Costs

Given the coupon rate b and the technology shock z, the firm's first-best liquidation policy is to choose a liquidation threshold z_d^{FB} so as to maximize firm value, instead of equity value. Since upon default the firm only recovers a fraction of unlevered firm value, it prefers to postpone default as late as possible in order to benefit from tax shields. However, the firm also incurs the fixed operating cost, and hence eventually suffers losses. Consequently, it is optimal to default at the abandonment threshold value $z_A(p)$, i.e., $z_d^{FB} = z_A$. Since $z_d^{FB} < z_d$, the equity-maximizing liquidation policy implies an inefficient early liquidation time.

More formally, given any liquidation threshold $y \geq z_A$, it can be shown that firm value is given by

$$v(z,b;p|y) = A(z;p) + \frac{b\tau}{r+\eta}\left[1 - \left(\frac{z}{y}\right)^\vartheta\right] - (1-\alpha)A(y;p)\left(\frac{z}{y}\right)^\vartheta, \tag{31}$$

Simple algebra shows that $v(z, b; p|y)$ is decreasing in y. Thus, the value-maximizing liquidation threshold $z_d^{FB} = z_A$, and the first-best firm value is given by

$$v^{FB}(z, b; p) = v(z, b; p|z_A) = A(z; p) + \frac{b\tau}{r + \eta}\left[1 - \left(\frac{z}{z_A}\right)^{\vartheta}\right]$$

That is, the first-best firm value is equal to unlevered firm value plus the probability-adjusted tax shield.

Due to the conflict of interest between shareholders and bondholders, the first-best liquidation policy cannot be enforced ex post. These agency costs are measured by the difference between the first-best firm value and firm value under the liquidation policy chosen by the shareholder. Formally, given the coupon rate b and the technology shock z, agency costs are given by:

$$\begin{aligned} c_A(z, b; p) &\equiv v^{FB}(z, b; p) - v(z, b; p) \\ &= \frac{b\tau}{r + \eta}\left[\left(\frac{z}{z_d}\right)^{\vartheta} - \left(\frac{z}{z_A}\right)^{\vartheta}\right] + (1 - \alpha)A(z_d; p)\left(\frac{z}{z_d}\right)^{\vartheta} > 0. \end{aligned} \tag{32}$$

Thus, agency costs consist of the loss of tax shields due to inefficient liquidation and the probability adjusted liquidation costs.

4 Stationary Equilibrium

This section derives a closed-form solution for the stationary equilibrium. I first consider the case where leverage is exogenous. Then I consider the case where leverage is chosen optimally. In both cases, the stationary equilibrium is unique and is obtained in closed form. The solution method follows from a similar procedure described in Hopenhayn and Rogerson (1993). It consists of three steps. The first step uses the entry condition (11) to determine the output price p^*, the second step uses condition (v) in the definition of equilibrium to find the invariant measure μ^* up to the scale factor N^*, and the third step uses the market clearing condition (iii) to determine the entry rate N^*.

4.1 Equilibrium with Exogenous Leverage

Throughout this subsection, the coupon rate b is assumed to be fixed exogenously.

Output Price It is easy to show that firm value v is strictly increasing in the output price p. When the output price is high enough, firm value exceeds the entry cost c_e. Then potential entrants have incentives to enter the industry. As more firms enter the industry, market competition drives down the output price. On the other hand, when the output price is low enough, firm value may be lower than the entry cost. In this case, no firm prefers to enter the industry. In sum, if there is positive entry, the equilibrium output price is determined by the entry condition (11). In particular, as p goes to infinity, the firm makes unbounded profits and hence v goes to infinity. However, as p goes to zero, the firm becomes unprofitable so that it is abandoned and v goes to zero. Thus, a unique equilibrium output price p^* is determined, as illustrated in Figure 2.

[Insert Figure 2 Here]

Exit Threshold Substituting the expressions for p^* into (6) and then substituting the resulting expression $a(p^*)$ into (23), one obtains the equilibrium exit threshold z_e :

$$z_e = z_d(b; p^*) = \left[\frac{\vartheta \lambda (b + c_f)}{(\vartheta - \gamma)(r + \eta) a(p^*)} \right]^{1/\gamma}. \tag{33}$$

This equation reveals that the impact of the product market competition on a firm's financing and liquidation/exit decisions is transmitted through the equilibrium output price.

Stationary Distribution of Incumbents Given the exit threshold z_e, the support of the stationary distribution of incumbents μ^* is $[z_e, \infty)$. Note that equation (15) implies that μ^* is linearly homogenous in N^*. Thus, it is convenient to scale μ^* by the factor N^* when solving it. In the appendix, I show that the density function for this stationary distribution is given by

$$N^* f(z) = N^* \begin{cases} G_1 z^{\beta_1 - 1} + G_2 z^{\beta_2 - 1}, & \text{for } z_e < z \leq \underline{z}, \\ A_1 z^{\beta_1 - 1} + A_2 z^{\beta_2 - 1} + \frac{1}{(\overline{z} - \underline{z})(\eta + \mu_z - \sigma_z^2)}, & \text{for } \underline{z} < z \leq \overline{z}, \\ H_1 z^{\beta_1 - 1}, & \text{for } z > \overline{z}. \end{cases} \tag{34}$$

where $\beta_1, \beta_2, A_1, A_2, G_1, G_2$ and H_1 are given in the appendix. The main idea to derive this density is that for this density to be constant over time, the rate at which firms arrive at any technology level in the support of the density is equal to the rate at which firms move away from that level (possibly suffering Poisson death).

The following lemma ensures that the signs of some equilibrium variables studied later make economic sense.

Lemma 1 *Assume* $\eta + \mu_z - \sigma_z^2 > 0$. *Then* $\beta_1 < 0$, $\beta_2 > 1$, $A_1 < 0$, $A_2 < 0$, $G_1 < 0$, $G_2 > 0$, $H_1 > 0$. *Moreover,* $f(z) > 0$ *for all* $z > z_e$.

Entry Rate The entry rate N^* is determined by the market-clearing condition (14). Specifically, by (5) and (13) aggregate output is given by

$$Y(\mu^*, b; p^*) = N^* I(\gamma) \left(\frac{p\nu}{r/(1-\tau)+\delta} \right)^{\nu\gamma}, \tag{35}$$

where $I(\cdot)$ is defined as

$$I(\chi) \equiv \int_{z_e}^{\infty} z^{\chi} f(z) dz, \tag{36}$$

for all $\chi < -\beta_1$. The restriction $\chi < -\beta_1$ ensures that $I(\chi)$ is finite. Equation (36) will be used repeatedly later and its explicit expression is given in the appendix.

Substitute (35) into (14) to obtain the entry rate

$$N^* = (p^*)^{-(\varepsilon+\gamma\nu)} I(\gamma)^{-1} \left(\frac{\nu}{r/(1-\tau)+\delta} \right)^{-\nu\gamma}, \tag{37}$$

Turnover Rate The turnover rate is an important measure of industry dynamics (see Dunne et al (1988) and Hopenhayn (1992a)). The *turnover rate* of entry is defined as the ratio of the mass of entrants to the mass of incumbents. The turnover rate of exit can be defined similarly. Since in a stationary equilibrium the entry rate is equal to the exit rate, these two measures of turnover are equal.

The total mass of incumbents M^* is equal to the full measure of the stationary distribution μ^* :

$$M^* = \int_{z_e}^{\infty} \mu^*(dz) = N^* \int_{z_e}^{\infty} f(z) dz = N^* I(0). \tag{38}$$

This equation implies that the turnover rate N^*/M^* is given by

$$\frac{N^*}{M^*} = \frac{1}{I(0)}. \tag{39}$$

Thus, the turnover rate of entry is equal to the inverse of the full measure implied by the scaled density f.

Average Industry Agency Costs The average industry agency cost is given by

$$\frac{1}{M^*} \int_{z_e}^{\infty} c_A(z, b; p^*) \mu^*(dz) = \frac{N^*}{M^*} \int_{z_e}^{\infty} c_A(z, b; w^*, r^*) f(z) dz.$$

where c_A is given in (32). Following Mello and Parsons (1992), the magnitude of average industry agency costs can be measured as the percentage of the average industry first-best firm value.

In summary, the above analysis implies the following characterization of the unique stationary equilibrium:

Theorem 2 *Assume that* $\lambda > 0$, $\eta + \mu_z > \sigma_z^2$ *and* $\beta_1 + \gamma < 0$, *where* β_1 *is given in the appendix and* λ *is given in (17). Then there is a unique stationary equilibrium with the coupon rate* b, (p^*, z_e, N^*, μ^*), *such that* $\underline{z} > z_e$. *It is characterized by equations (11), (33), (34), and (37).*

The assumptions $\lambda > 0$ and $\beta_1 + \gamma < 0$ ensure that the present value of the profit flow and the integrals $I(\gamma)$, $I(0)$ and $I(\vartheta)$ are finite. The assumption $\eta + \mu_z > \sigma_z^2$ ensures that the condition in Lemma 1 is satisfied. Finally, the requirement $\underline{z} > z_e$ guarantees that the initial draw of technology shock is not trivial in the sense that no firm immediately exits upon entry.

Note that when there is no debt (i.e., $b = 0$), firms are all equity financed and the model reduces to the industry dynamics model studied by Hopenhayn (1992a). The only difference is that here the technology shock is modelled as a geometric Brownian motion process, whereas it is modelled as a mean reversion process in Hopenhayn (1992a).

4.2 Equilibrium with Endogenous Leverage

If the firm chooses its optimal capital structure, then it selects the coupon rate $b^*(p)$ to solve problem (28). The equilibrium output price p^o is then determined by the entry condition

$$\int_{\underline{z}}^{\overline{z}} v(z, b^*(p); p)\zeta(dz) = c_e. \tag{40}$$

Now, the equilibrium with endogenous leverage can be characterized in the same manner as that with exogenous leverage except for the following changes: (i) the output price p^* is replaced by the above value p^o, (ii) the coupon rate b takes the value $b^o \equiv b^*(p^o)$, and (iii) the exit threshold z_e takes the value $z_e^o = z_e(b^o; p^o)$. I omit the details.

Importantly, if there is no fixed operating cost (i.e., $c_f = 0$), then the equilibrium with endogenous leverage can be characterized completely in closed-form. Specifically, the optimal coupon rate $b^*(p)$ is given by (30). Substituting (30) into equation (23) yields the equilibrium exit threshold

$$\begin{aligned} z_e^o &= z_d(b^*(p^o);p^o) = \left[\frac{\vartheta}{\vartheta-\gamma}\frac{\lambda b^*(p^o)}{(r+\eta)a(p^o)}\right]^{1/\gamma} \\ &= \left[\frac{\gamma-\vartheta}{\gamma} - \frac{\vartheta(1-\alpha)\,(1-\tau)}{\gamma\tau}\right]^{\frac{1}{\vartheta}} E_\zeta\left[z^\vartheta\right]^{\frac{1}{\vartheta}}. \end{aligned} \tag{41}$$

Notice that this expression implies that the exit threshold does not depend on the output price. This result is not robust to the introduction of the fixed operating cost.

Substituting (27), (30), and (41) into (40), one can solve for the unique equilibrium output price p^o :

$$p^o = (c_e)^{\frac{1}{\gamma}}\left\{(1-\nu)\left(\frac{\nu}{r/(1-\tau)+\delta}\right)^{\nu\gamma}\left[\frac{1-\tau}{\lambda}\frac{\overline{z}^{\gamma+1}-\underline{z}^{\gamma+1}}{(\overline{z}-\underline{z})(\gamma+1)}+\frac{\tau}{\lambda}(z_e^o)^\gamma\right]\right\}^{-\frac{1}{\gamma}}. \tag{42}$$

Once the equilibrium output price and exit threshold are obtained, the equilibrium entry rate N^o and the equilibrium stationary distribution of incumbents μ^o can be derived in the same manner as before. Hence, the unique stationary equilibrium (p^o, z_e^o, N^o, μ^o) is fully characterized.

5 Results

To examine the implications of the model, I first calibrate a base case model. I then conduct simulations based on this model. For all simulations, input parameter values are chosen such that the conditions of Theorem 2 are satisfied.

5.1 Calibration

The base case model studies the equilibrium with optimal leverage. The calibration of parameters follows a standard procedure in the business cycle literature (e.g., Kydland and Prescott (1982)). Namely, the parameter values are either estimated directly from the data or chosen such that the model's equilibrium behavior matches some measured statistics as closely as possible.

I first set the fixed operating cost $c_f = 0$ so that there is a closed-form solution to the unique equilibrium. I then set the price elasticity of demand $\varepsilon = 0.75$. This number is within the range estimated by Phillips (1995).

Next, I calibrate parameters related to technology. Set the returns-to-scale parameter $\nu = 0.40$, as estimated by Caballero and Engel (1999). This implies $\gamma = 1/(1-\nu) = 1.667$. As in the business cycle literature, set the depreciation rate of capital $\delta = 0.1$. In order to calibrate the drift μ_z and volatility σ_z, use $\pi(z_t; p)$ to proxy a firm's cash flow. The growth rate and volatility of cash flows are roughly equal to 2.5% and 25% for a typical Standard & Poor's 500 firm. Thus, apply Ito's Lemma to equation (3) to derive that $\sigma_z = 0.25/\gamma = 15\%$ and $\mu_z = (0.025 - 0.5\gamma(\gamma - 1)\sigma_z^2)/\gamma = 0.75\%$

Set the risk free $r = 5.22\%$ so that it is equal to the rate on 10-year Treasury bonds as of January 30, 2001, as reported in the February 7, 2001 edition of Standard & Poor's *The Outlook*. Set the corporate tax rate $\tau = 34\%$, as estimated by Graham (1996). Set the bankruptcy cost parameter $1 - \alpha = 20\%$, which is at the upper bound of recent estimates reported in Andrade and Kaplan (1998).

Set the Poisson death parameter $\eta = 4\%$. This number follows from the facts that the annual turnover rate is roughly 7% (see Dunne *et al* (1988) and Hopenhayn (1992b)) and that the default rate is roughly 3% (see Brady and Bos (2002)).

It remains to calibrate the parameters c_e, $\underline{z}$, and $\overline{z}$. First, follow Hopenhayn (1992b) and normalize the equilibrium output price $p^o = 1$. Next, use equation (40) to determine c_e once $\underline{z}$ and $\overline{z}$ are known. Finally, choose values for $\underline{z}$ and $\overline{z}$ so that the following numbers are roughly matched: (i) The average industry Tobin's q is equal to 2.7, which is in the range estimated by Lindenberg and Ross (1981). (ii) The turnover rate is 7%.

The base case parameter values are summarized in Table 1.

[Insert Table 1 here]

5.2 The Base Case Model

The equilibrium for the base case model is reported in the first row of Table 2. It shows that the average industry leverage ratio is equal to 23.09%. This number is close to the historical average leverage ratio (25%) reported in Barclay *et al* (2002). To compare with the standard single firm EBIT-based contingent claims model, I adopt the same parameter values for a single risk neutral firm. The optimal leverage ratio is 71.59%, which is much higher than that typically observed in practice.[8] The main reason that the present model predicts low leverage is that I compute equilibrium average industry leverage level, instead of a single firm's leverage. In a stationary equilibrium, there are not many surviving firms having high leverage levels.

[Insert Table 2 Here]

[8] For a wide range of reasonable parameter values, the Leland-style single firm contingent claims model typically predicts a much higher leverage ratio than that observed in practice. However, dynamic capital structure models such as Goldstein et al (2001), Ju et al (2003), and Miao and Morellec (2003) can predict lower leverage ratios .

Table 2 also reports the industry tax advantage of debt, which is measured as

$$\frac{\int_{z_e^o}^{\infty} \frac{b^o \tau}{r+\eta} \left[1 - (z/z_e^o)^{\vartheta}\right] \mu^o(dz)}{\int_{z_e^o}^{\infty} v(z, b^o; p^o) \mu^o(dz)} \times 100\%.$$

The value is 7.08%, which is close to the estimate (9.7%) reported in Graham (2000).

Figure 3 plots the stationary distribution of surviving firms. This figure implies that more efficient firms are less likely to exit, since they have higher technology (productivity) levels which are farther away from the exit threshold. This prediction is consistent with the empirical finding reported by Kovenock and Phillips (1997).

Another property of the base case model is that although all firms in the industry are ex ante identical, and hence pay the same amount of coupon, the leverage ratios vary across firms. This is because surviving firms differ in realizations of technology shocks so that they have different equity value.[9] This result is related to the empirical finding of Welch (2004) that leverage changes are mainly determined by equity returns.

Simulations reported in Table 2 also reveal that agency costs account for 2.57% of the first-best firm value. In later simulations, I find that the magnitude of agency costs is approximately 2% for a wide range of parameter values. Thus, the agency costs arising from the conflict of interest between shareholders and bondholders are quite small. A similar finding is reported in Parrino and Weisbach (1999).

To compare with Hopenhayn's (1992a) industry dynamics model without debt financing, I set the fixed operating cost $c_f = 5$ and compute equilibria with and without debt financing. The equilibrium outcome for the model with debt financing is reported in the 12th row of Table 2. By contrast, when firms do not take into account tax advantages of debt and are all equity financed, industry output is 0.72, the turnover rate is 4.77%, and average industry firm value is \$372.12, all of which are lower than the model with debt financing. Thus, debt financing not only raises firm value,[10] but also facilitates efficient exit and increases industry output. The intuition is simple. Debt increases the exit threshold (see equations (20) and (23)), and hence induces inefficient firms to exit. In addition, increased firm value promotes entry. Competition then drives down the output price and raises industry output.

5.3 Comparative Statics

Since capital structure and production decisions may simultaneously respond to changes in exogenous factors, I focus on the stationary equilibrium with optimal leverage and examine

[9] Maksimovic and Zechner (1991) attribute the variation of capital structures to the adoption of different technologies within the industry.

[10] Average industry firm value is \$395.57 in the present model. This number is not reported in Table 2.

comparative static properties of the equilibrium based on the base case model studied earlier.

Technology Growth and Entry Distribution Figure 3 plots the impact of technology growth on average industry leverage, industry output, and the turnover rate. As argued in the introduction, the standard single firm tradeoff model cannot explain the empirical evidence that high-growth firms have low leverage. However, in the present industry equilibrium framework, the tradeoff theory can still explain this fact. This is because the price feedback effect discussed in the introduction plays an important role. Simulations reported in Table 2 show that this effect dominates so that the optimal coupon rate falls and the liquidation threshold rises with technology growth μ_z. Table 2 also reveals that the tax benefit of debt falls and average industry leverage falls with μ_z.

Since the market-to-book ratio is positively related to technology growth,[11] it is negatively related to leverage. The usual interpretation of this fact is based on the underinvestment problem of debt identified by Myers (1977) or the free cash flow theory of Jensen (1986). Two recent interpretations are offered by Welch (2002) and Baker and Wurgler (2002). The present model, however, offers a new interpretation in an industry equilibrium setting.

To examine why the price feedback effect may dominate and how robust the result is, consider the expression for the before-tax present value of profits (16),

$$\Pi(z;p) = \frac{p^{\gamma}(1-\nu)\left(\frac{\nu}{r/(1-\tau)+\delta}\right)^{\nu\gamma}}{r+\eta-\mu_z\gamma-\sigma_z^2\gamma(\gamma-1)/2} z^{\gamma} - \frac{c_f}{r+\eta}.$$

where I have substituted the expressions for $a(p)$ and λ, (6), and (17). If $\Pi(z;p)$ is price elastic (i.e., $\gamma > 1$), and if the level and changes of the growth rate μ_z are small, then the decrease in the price p may well dominate the increase in μ_z. In the present model, under decreasing-returns-to-scale technology, γ must be bigger than 1. Moreover, for a typical firm the growth rate of cash flows and its change are unlikely to be high. Therefore, I conclude that the result is quite robust for a wide range of reasonable parameter values.

The increase in μ_z also has a positive selection effect because it changes the liquidation threshold and the stationary distribution of firms. Figure 4 illustrates that this effect causes the scaled density function to shift to the right. Thus, to survive in the industry, firms must have high productivity or technology levels. This makes entry tougher. Thus, the turnover rate decreases. Formally, this can be seen from equation (39) because the full measure implied by the density f rises with μ_z.

[11] Simulations (not reported in Table 2) confirms this positive correlation. The market-to-book ratio is a commonly used proxy for growth opportunities.

[Insert Figures 3 and 4 Here]

Notice that even though the increase in technology growth may cut the present value of profits, the average industry equity value and firm value rise with technology growth. Simulations show that, when μ_z increases from 0.75% to 1.5%, average industry equity value increases from \$203.57 to \$1338.2 and average industry firm value increases from \$264.68 to \$1400.8. This is because those values are computed using the stationary distribution of surviving firms, e.g., the average industry equity value is equal to $\frac{1}{M^o}\int_{z_e^o}^{\infty} e(z, b^o; p^o)\mu^o(dz)$. In addition, the positive selection effect implies that a high-growth industry has a greater number of highly efficient firms than a low-growth industry. These highly efficient firms have higher equity value and firm value. Furthermore, simulations show that the size M^0 of the high-growth industry is much lower than that of the low-growth industry.

The impact of an improvement of the entry distribution (i.e., an increase in $\overline{z}$) is similar to that of an increase in technology growth, as reported in Table 2. So I omit the discussion.

Risks of Technology Figure 5 plots the relation between technology volatility, average industry leverage, industry output, and the turnover rate. As in the standard contingent claims model, the volatility parameter σ_z provides a measure of bankruptcy risk and hence is an important determinant of leverage. Figure 5 reveals that volatility is negatively related to average industry leverage. This prediction is similar to that in the single firm model and is consistent with the empirical evidence documented by Titman and Wessels (1988).

[Insert Figures 5-6 Here]

Figure 5 also reveals that volatility is positively related to industry output. This is because an increase in σ_z has an option effect in that it raises the option value of waiting to default. This results in higher firm value and hence encourages entry. Competition then drives down the output price and raises industry output.

Figure 5 reveals that volatility is positively related to the turnover rate. This is due to the selection effect, as illustrated in Figure 6. Simulations reported in Table 2 show that the selection effect causes the full measure implied by the scaled density f to decrease with volatility, leading to an increased turnover rate.

Bankruptcy Cost and Corporate Tax An increase in the bankruptcy cost parameter $1-\alpha$ has a negative cash flow effect. This effect decreases the value of an active firm and depresses entry. As a result, the output price rises and industry output falls. Figure 7 plots the impact of the bankruptcy cost on industry output, as well as its impact on average industry leverage and the turnover rate.

While it is intuitive that bankruptcy costs are negatively related to leverage, Figure 7 also reveals that bankruptcy costs are negatively related to the turnover rate. The intuition is that an increase in the bankruptcy cost lowers debt and hence decreases the opportunity cost of remaining active. Thus, each incumbent prefers to stay longer in the industry. Consequently, the liquidation threshold falls as reported in Table 2. The lower value of the liquidation threshold implies less selection and higher expected lifetime of firms. As a result, the turnover rate falls. Figure 8 illustrates the selection effect.

[Insert Figures 7-9 Here]

An increase in the corporate tax rate has the same negative cash flow effect as an increase in the bankruptcy cost so that industry output falls with the tax rate. However, the increase in the corporate tax rate has an opposite effect on leverage and turnover to an increase in the bankruptcy cost, as reported in Table 2 and Figure 9. I omit the detailed analysis.

Fixed Operating Cost So far, I have set the fixed operating cost c_f to be zero. Because the fixed cost is related to the degree of economies of scale, I now examine the impact of the fixed operating cost on equilibrium outcomes, which is illustrated in Figure 10.[12]

Figure 10 reveals that the fixed cost is positively related to the turnover rate, and negatively related to industry output and leverage. The intuition is as follows. An increase in the fixed operating cost lowers the operating profit and hence lowers firm value. This depresses entry, raises the output price, and hence lowers industry output. As reported in Table 2, the positive price feedback effect is dominated so that each incumbent prefers to exit earlier, resulting in an increased exit threshold and an increased turnover rate. This positive selection effect is illustrated in Figure 11.

[Insert Figures 10-11 Here]

I now analyze the impact on leverage. While the increased fixed cost lowers the tax benefit of debt, it also lowers unlevered firm value and hence bankruptcy costs. Simulations reported in Table 2 reveals that the latter effect dominates so that the optimal coupon rises. Thus, the average industry value of debt also rises. However, due to the positive selection and price effects, average industry firm value also increases with the fixed cost. The intuition is that, following an increase in the fixed cost, surviving firms are more efficient since the

[12] As a robustness check, I redo all previous simulations for a number of positive values of the entry cost. I find the results do not change qualitatively.

exit threshold is higher and the positive price effect is stronger for those firms. A similar result is derived in Hopenhayn (1992a,b) for all equity financed firms. Simulations reported in Table 2 show that the increase in firm value dominates the increase in debt value so that average industry leverage falls with the fixed cost.

Entry Cost In the short run, an increase in the entry cost c_e does not affect a firm's cash flows and its liquidation decision. Thus, it does not affect the value of an active firm. However, the entry cost acts as a barrier to entry. High entry costs protect incumbents and drive up the industry output price. This price feedback effect will generally influence financing and exit decisions.

Specifically, the increase in the output price raises the benefit of remaining active and the tax advantage of debt. Thus, each firm prefers to issue more debt and hence the optimal coupon rises. However, this leads to an increased opportunity cost of remaining active. The impact on the exit threshold depends on these two opposite effects as shown in equation (24). When there is no fixed operating cost, these effects offset each other so that changes in the entry cost do not affect the exit threshold (see equation (41)). Consequently, these changes do not have a selection effect.

However, this result is not robust to the introduction of the fixed operating cost. To illustrate this point, I set the operating cost $c_f = 5$. Figure 12 plots the impact of the entry cost on leverage, output, and the turnover rate. It reveals that the entry cost is positively related to leverage and negatively related to the turnover rate.[13] The intuition is that, following an increase in the entry cost, the positive price feedback effect dominates so that the exit threshold decreases (see simulations reported in Table 2). Thus, default/exit probabilities are lower, and hence expected bankruptcy costs are lower. This results in higher leverage.

The negative relation between the entry cost and the turnover rate is due to the negative selection effect, as illustrated in Figure 13. This prediction is consistent with the evidence reported by Orr (1974) for Canadian industry. A similar result is derived by Hopenhayn (1992a) for all equity financed firms.

[Insert Figures 12-13 Here]

[13]This result does not depend on the choice of $c_f = 5$ since it is verified by simulations for many other values of c_f.

6 Debt Reorganization

So far, I have assumed that the capital structure decision is made ex ante at the entry stage and then fixed throughout the firm's lifetime. However, firms may re-adjust their debt levels ex post either because technology may improve over time so that firms prefer to issue more debt or because technology shock is bad enough so that firms are in financial distress and prefer to reorganize debt.

Contingent-claim models of debt reorganization and dynamic capital structure include Fischer et al (1989), Mella-Barral and Perraudin (1997), Leland (1998), Mella-Barral (1995, 1999), Fan and Sundaresan (2000), Goldstein et al (2001), François and Morellec (2002), Titman and Tsyplakov (2002), Ju et al (2003), and Miao and Morellec (2003) among others. I argue that as long as there is a stationary liquidation threshold, these models can be embedded in the present industry equilibrium framework. To illustrate this point, I consider a simple model where debt is reorganized when firms are in financial distress. Gilson, Kose, and Lang (1990) find that almost half the companies in financial distress avoid liquidation through out-of-court debt reorganization (also see Franks and Torous (1994)).

I consider a particular type of out-of-court debt reorganization – debt exchange offers. In a debt exchange offer, bondholders exchange their old debt contract for a new one with a reduced coupon repayment. I adopt the model of debt exchange offers developed by Mella-Barral (1995). This model is also applied by Lambrecht (2001) in a duopoly framework. By contrast, I study debt exchange offers in a perfectly competitive industry framework.

Consider a single firm's decision in a competitive industry with the output price p. Assume that all debt is held by a bank and debt reorganization takes place through a one-off take-it-or-leave-it offer made by management. Furthermore, assume that shareholders are unwilling to postpone debt exchange offers beyond the point where direct liquidation becomes optimal. Similar assumptions are made in Mella-Barral (1995) and Lambrecht (2001).

A debt exchange occurs when the technology shock falls below a threshold level z_x. At this point, the existing debt contract is swapped for a new one with coupon $\underline{b}$ which is less than the old coupon b. The previous assumption implies that $z_x \geq z_d(b;p)$, where $z_d(b;p)$ is the liquidation threshold for the old debt contract; it is given in (23).

I start by deriving equity value and debt value when the firm has a debt exchange option available.

Proposition 3 *Suppose that at the first time when the technology shock falls below a threshold value z_x the old debt contract with coupon b is exchanged for a new contract with reduced coupon $\underline{b}$. Then the value of the equity and the debt prior to reorganization are respectively* *given by*

$$
\begin{aligned}
& e_x(z, z_x, b, \underline{b}; p) \\
= \quad & (1-\tau)\left[\Pi(z;p) - \frac{b}{r+\eta}\right] + \left\{e(z_x, \underline{b}; p) - (1-\tau)\left[\Pi(z_x;p) - \frac{b}{r+\eta}\right]\right\}\left(\frac{z}{z_x}\right)^{\vartheta} \quad (43)
\end{aligned}
$$

$$
d_x(z, z_x, b, \underline{b}; p) = \frac{b}{r+\eta} + \left(d(z_x, \underline{b}; p) - \frac{b}{r+\eta}\right)\left(\frac{z}{z_x}\right)^{\vartheta}. \quad (44)
$$

I next determine the optimal timing of the debt exchange and the corresponding new coupon, i.e., $(z_x, \underline{b})$. Assume that shareholders have all the bargaining power so that management maximizes equity value subject to the constraint that the bank is indifferent between accepting or rejecting the offer. That is, debt value after a successful debt exchange is equal to the value after the offer is turned down. Therefore, the optimal debt exchange offer solves the following problem:

$$
\max_{z_x, \underline{b}} e_x(z_t, z_x, b, \underline{b}; p), \;\; z_t \geq z_x,
$$

subject to

$$
d(z_x, \underline{b}; p) = d(z_x, b; p). \quad (45)
$$

Solving this problem leads to the following proposition.

Proposition 4 *The optimal debt exchange offer happens when the firm finds it optimal to default, i.e.,* $z_x = z_d(b;p)$*. The corresponding new coupon* $\underline{b}$ *is the solution to*

$$
\frac{b}{\underline{b}} - 1 = \frac{\gamma - \vartheta(1-\alpha(1-\tau))}{\vartheta - \gamma}\left[\left(\frac{b+c_f}{\underline{b}+c_f}\right)^{\frac{\vartheta}{\gamma}} - \frac{b}{\underline{b}}\right]. \quad (46)
$$

After analyzing a single firm's debt exchange offer decision, I now turn to the stationary industry equilibrium. As in section 3, the equilibrium output price p^* is determined by the entry condition. That is, the ex ante value of the firm is equal to the entry cost. The exit threshold z_e is then given by $z_e = z_d(\underline{b}; p^*)$. The equilibrium stationary distribution of surviving firms μ^* has the support $[z_d(\underline{b}; p^*), \infty)$. Different from the model analyzed in previous sections, surviving firms may issue different amounts of debt because some firms may reorganize their debt.

In the above analysis, I assume the initial coupon b is fixed and determine optimal debt exchange offers given b. Recognizing future debt exchange options and the impact of debt on firms' production, entry and exit decisions, firms have incentives to choose optimal b so as to maximize ex ante firm value as in section 4.2. A thorough quantitative analysis as in section 5 is beyond the scope of the present paper.

7 Conclusion

In this paper, I present an equilibrium model of industry dynamics and capital structure decisions. I show that technology (productivity) heterogeneity is important in determining a firm's survival probabilities and leverage ratio. In particular, in equilibrium there is a stationary distribution of surviving firms. These firms exhibit a wide variation of capital structures. In addition, more efficient firms are less likely to exit. Finally, I analyze comparative static properties of changes in technology growth, technology risk, entry distribution, entry cost, fixed cost, bankruptcy cost, and tax policy.

The analysis reveals that the interaction between financing and production decisions is important in industry equilibrium. In particular, it shows that several conclusions reached in standard single-firm contingent claims models do not hold true in an equilibrium setting. Moreover, it moves predictions in the right direction in terms of reconciling the evidence. Specifically, the analysis shows that either one of the following exogenous factors can simultaneously explain the empirical findings mentioned in the introduction: the slowdown of technology (productivity) growth, the deterioration of entry distribution, or the increase in the corporate tax rate.

The paper also provides a number of new testable predictions regarding capital structure and industry dynamics. First, industries associated with high technology growth and better entry distribution tend to have low average leverage, low turnover rates, and high output. Second, industries associated with high risks of technology tend to have low average leverage, high turnover rates, and high output. Third, industries associated with high bankruptcy costs tend to have low average leverage, low turnover rates, and low output. Fourth, industries associated with high fixed operating costs tend to have low average leverage, high turnover rates, and low output. Finally, industries associated with high entry costs tend to have high average leverage, low turnover rates, and low output.

The paper could be extended in several directions, which are left for future research. First, in the paper, the expected returns of equity and other macroeconomic variables are constant. To study equity premium and other time series behavior of the industry, it is necessary to introduce aggregate uncertainty. Second, this paper considers only the conflict of interest between shareholders and bondholders. It would be interesting to study the conflict of interest between shareholders and managers. Third, in section 6, I outline a simple industry equilibrium model of debt reorganization. It would be interesting to consider a richer model of dynamic capital structure. Finally, it would be interesting to consider finite maturity debt. This requires a constant default threshold in stationary equilibrium, which can be delivered using the framework of Leland and Toft (1996) or Leland (1998).

A Appendix

Derivation of equity value (22) and unlevered firm value (18):

When the default threshold is y, equity value is

$$e(z,b;p|y) = (1-\tau)E^z\left[\int_0^{T_y} e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right].$$

This expression is equal to

$$\begin{aligned}
& (1-\tau)E^z\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right] - (1-\tau)E^z\left[\int_{T_y}^{\infty} e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right] \\
= \; & (1-\tau)E^z\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right] - (1-\tau)E^y\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t;p)-b)dt\right] \\
& \times E^z\left[e^{-(r+\eta)T_y}\right],
\end{aligned}$$

where the last equality follows from the strong Markov property of the process $(z_t)_{t\geq 0}$ (see Karatzas and Shreve (1991, p. 82)). By an argument similar to that in Karatzas and Shreve (1991, p. 197),

$$E^z\left[e^{-(r+\eta)T_y}\right] = \left(\frac{z}{y}\right)^{\vartheta},$$

where ϑ is given in (19). Equation (22) follows from the above expressions and (16).

Equation (18) can be derived by letting $b=0$ in the above analysis. ■

Derivation of the stationary distribution of firms:

It is convenient to work in terms of the logarithm, $x = \log z$. Then (x_t) is a Brownian motion satisfying:

$$dx_t = \mu_x dt + \sigma_x dW_t,$$

where $\mu_x = \mu_z - \frac{1}{2}\sigma_z^2$ and $\sigma_x = \sigma_z$. Because the initial draw of z is uniform over $[\underline{z}, \overline{z}]$, the initial draw of $x = \log(z)$ has an exponential distribution over $[\underline{x}, \overline{x}]$ where $\overline{x} = \log \overline{z}$ and $\underline{x} = \log \underline{z}$. This distribution has a density function

$$g(x) = \exp(x - \widehat{x}),$$

where $\widehat{x} = \log(\overline{z} - \underline{z})$.

Let the stationary distribution of incumbent firms have a density function $N^*\phi(x)$ on $[x_e, \infty)$, where $x_e = \log(z_e)$ and N^* is the entry rate determined later. I will now use the Kolmogorov equation to find the function $\phi(x)$ by considering three cases.

I adapt the heuristic argument from Dixit and Pindyck (1994, Chapter 8). First, approximate the Brownian motion by a random walk. To do so, divide time into short intervals of duration dt, and the x space into short segments, each of length $dh = \sigma_x \sqrt{dt}$. Of the firms located in one such segment, during time dt a proportion ηdt will die. Of the rest, a fraction p will move one segment to the right, and a fraction q will move to the left, where

$$p = \frac{1}{2}\left[1 + \frac{\mu_x}{\sigma_x}\sqrt{dt}\right],\ q = \frac{1}{2}\left[1 - \frac{\mu_x}{\sigma_x}\sqrt{dt}\right].$$

Now consider the first case where $\underline{x} \leq x < \overline{x}$. Then there are new entrants having the shock x since the support of their initial draw of shocks is $[\underline{x}, \overline{x}]$. There are $N^*\phi(x)dh$ firms in the segment centered at x. In the next unit of time period dt, all of these move away with either Poisson or Brownian shocks. New entrants, as well as firms from the left and right, arrive to take their places. For balance,

$$\begin{aligned} N^*\phi(x)dh &= N^*dtg(x)dh + p(1-\eta dt)N^*\phi(x-dh)dh \\ &\quad + q(1-\eta dt)N^*\phi(x+dh)dh. \end{aligned}$$

Apply Taylor's Expansion Theorem and simplify to obtain the ODE:

$$\frac{1}{2}\sigma_x^2\phi''(x) - \mu_x\phi'(x) - \eta\phi(x) + g(x) = 0.$$

A particular solution to this equation can be derived as

$$\phi_0(x) = e^{x-\widehat{x}}/(\eta + \mu_x - \sigma_x^2/2).$$

To make economic sense, I assume that $\eta + \mu_x - \sigma_x^2/2 = \eta + \mu_z - \sigma_z^2 > 0$. Then the general solution is given by

$$\phi(x) = A_1 e^{\beta_1 x} + A_2 e^{\beta_2 x} + \phi_0(x),\ \text{for } \underline{x} \leq x < \overline{x},$$

where

$$\beta_1 = \frac{\mu_x - \sqrt{\mu_x^2 + 2\sigma_x^2\eta}}{\sigma_x^2},\ \beta_2 = \frac{\mu_x + \sqrt{\mu_x^2 + 2\sigma_x^2\eta}}{\sigma_x^2},$$

and A_1 and A_2 are constants to be determined.

In the second case, $x_e < x < \underline{x}$, there is no new entrant in the segment centered at x. Apply a similar method to show that ϕ satisfies the following ODE:

$$\frac{1}{2}\sigma_x^2\phi''(x) - \mu_x\phi'(x) - \eta\phi(x) = 0.$$

The general solution to this equation is given by

$$\phi(x) = G_1 e^{\beta_1 x} + G_2 e^{\beta_2 x}, \text{ for } x_e < x < \underline{x},$$

where G_1 and G_2 are constants to be determined.

In the third case, $x \geq \overline{x}$, there is no new entrant in the segment centered at x either so that ϕ still satisfies the above ODE. Let the solution be

$$\phi(x) = H_1 e^{\beta_1 x} + H_2 e^{\beta_2 x}, \text{ for } x \geq \overline{x},$$

where H_1 and H_2 are constants to be determined.

In terms of z, the density function of μ^* is given by $N^* f(z) = \frac{N^*}{z}\phi(\log(z))$, which gives (34).

The constants A_1, A_2, G_1, G_2, H_1, and H_2 are determined by the following six boundary conditions:

$$\int_{\overline{x}}^{\infty} \phi(x)dx < \infty, \tag{47}$$

$$\phi(x_e) = 0, \tag{48}$$

$$\lim_{x \uparrow \underline{x}} \phi(x) = \lim_{x \downarrow \underline{x}} \phi(x), \tag{49}$$

$$\lim_{x \uparrow \underline{x}} \phi'(x) = \lim_{x \downarrow \underline{x}} \phi'(x), \tag{50}$$

$$\lim_{x \uparrow \overline{x}} \phi(x) = \lim_{x \downarrow \overline{x}} \phi(x), \tag{51}$$

$$\lim_{x \uparrow \overline{x}} \phi'(x) = \lim_{x \downarrow \overline{x}} \phi'(x). \tag{52}$$

Equation (47) says that the total mass of incumbents must be finite. Equation (48) is derived from the fact that when the process (x_t) falls to x_d, the firm exits the industry. Finally, equations (49)-(52) follow from Theorem 4.4.9 in Karatzas and Shreve (1991, p. 271). Using these equations, one can derive that $H_2 = 0$ and G_1, G_2, A_1, A_2, H_1 solve the following system of linear equations:

$$\begin{aligned}
G_1 e^{\beta_1 x_e} + G_2 e^{\beta_2 x_e} &= 0, \\
G_1 e^{\beta_1 \underline{x}} + G_2 e^{\beta_2 \underline{x}} &= A_1 e^{\beta_1 \underline{x}} + A_2 e^{\beta_2 \underline{x}} + \phi_0(\underline{x}), \\
G_1 \beta_1 e^{\beta_1 \underline{x}} + G_2 \beta_2 e^{\beta_2 \underline{x}} &= A_1 \beta_1 e^{\beta_1 \underline{x}} + A_2 \beta_2 e^{\beta_2 \underline{x}} + \phi_0'(\underline{x}), \\
A_1 e^{\beta_1 \overline{x}} + A_2 e^{\beta_2 \overline{x}} + \phi_0(\overline{x}) &= H_1 e^{\beta_1 \overline{x}}, \\
A_1 \beta_1 e^{\beta_1 \overline{x}} + A_2 \beta_2 e^{\beta_2 \overline{x}} + \phi_0'(\overline{x}) &= H_1 \beta_1 e^{\beta_1 \overline{x}}.
\end{aligned}$$

The solution in terms of z is

$$\begin{aligned}
A_1 &= \frac{(1-\beta_1)\, z_e^{\beta_2-\beta_1}\left(\overline{z}^{1-\beta_2}-\underline{z}^{1-\beta_2}\right)+(1-\beta_2)\,\underline{z}^{1-\beta_1}}{(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\,(\eta+\mu_z-\sigma_z^2)}, \\
A_2 &= -\frac{(1-\beta_1)\,\overline{z}^{1-\beta_2}}{(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\,(\eta+\mu_z-\sigma_z^2)}, \\
G_1 &= \frac{(1-\beta_1)\, z_e^{\beta_2-\beta_1}\left(\overline{z}^{1-\beta_2}-\underline{z}^{1-\beta_2}\right)}{(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\,(\eta+\mu_z-\sigma_z^2)}, \\
G_2 &= \frac{(1-\beta_1)\,(\underline{z}^{1-\beta_2}-\overline{z}^{1-\beta_2})}{(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\,(\eta+\mu_z-\sigma_z^2)}, \\
H_1 &= \frac{(1-\beta_1) z_e^{\beta_2-\beta_1}\left(\overline{z}^{1-\beta_2}-\underline{z}^{1-\beta_2}\right)+(\beta_2-1)\left(\overline{z}^{1-\beta_1}-\underline{z}^{1-\beta_1}\right)}{(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\,(\eta+\mu_z-\sigma_z^2)}. \blacksquare
\end{aligned}$$

Derivation of the expression in (36):

Substituting the expression for f in (34), one can derive that

$$\begin{aligned}
I(\chi) &\equiv \int_{z_e}^{\infty} z^{\chi} f(z) dz \qquad (53) \\
&= \frac{G_1}{\beta_1+\varepsilon}\left(\underline{z}^{\beta_1+\chi}-(z_e)^{\beta_1+\chi}\right)+\frac{G_2}{\beta_2+\varepsilon}\left(\underline{z}^{\beta_2+\chi}-(z_e)^{\beta_2+\chi}\right) \\
&\quad +\frac{A_1}{\beta_1+\chi}\left(\overline{z}^{\beta_1+\chi}-\underline{z}^{\beta_1+\chi}\right)+\frac{A_2}{\beta_2+\chi}\left(\overline{z}^{\beta_2+\chi}-\underline{z}^{\beta_2+\chi}\right) \\
&\quad +\frac{\overline{z}^{\chi+1}-\underline{z}^{\chi+1}}{(\chi+1)(\overline{z}-\underline{z})(\eta+\mu_z-\sigma_z^2)}-H_1\frac{\overline{z}^{\beta_1+\chi}}{\beta_1+\chi},
\end{aligned}$$

for all $\chi < -\beta_1$. $\blacksquare$

Proof of Lemma 1:

Observe that β_1 and β_2 are two roots of the equation

$$\mathcal{Q}(\beta) = \frac{1}{2}\sigma_x^2\beta^2 - \mu_x\beta - \eta = 0.$$

Since $\mathcal{Q}(1) = \sigma_x^2/2 - \mu_x - \eta = \sigma_z^2 - \eta - \mu_z < 0$, $\mathcal{Q}(0) = -\eta < 0$, $\lim_{\beta\to\infty}\mathcal{Q}(\beta) = \lim_{\beta\to-\infty}\mathcal{Q}(\beta) = \infty$, it follows from the Intermediate Value Theorem that $\beta_1 < 0$ and $\beta_2 > 1$.

Note that A_1, A_2, G_1, G_2, and H_1 has the same positive denominator $(\beta_2-\beta_1)\,(\overline{z}-\underline{z})\left(\eta+\mu_z-\sigma_z^2\right) > 0$. Since $\beta_1 < 0$ and $\beta_2 > 1$, it follows that $A_1 < 0$, $A_2 < 0$, $G_1 < 0$, and $G_2 > 0$.

Finally, the numerator of H_1 is equal to

$$\begin{aligned}
& (1-\beta_1) z_e^{\beta_2-\beta_1}\left(\overline{z}^{1-\beta_2}-\underline{z}^{1-\beta_2}\right)+(\beta_2-1)\left(\overline{z}^{1-\beta_1}-\underline{z}^{1-\beta_1}\right) \\
= \; & (1-\beta_1)(\beta_2-1) z_e^{-\beta_1}\left[\frac{z_e^{\beta_1}\left(\overline{z}^{1-\beta_1}-\underline{z}^{1-\beta_1}\right)}{1-\beta_1}-\frac{z_e^{\beta_2}\left(\overline{z}^{1-\beta_2}-\underline{z}^{1-\beta_2}\right)}{1-\beta_2}\right] \\
= \; & (1-\beta_1)(\beta_2-1) z_e^{-\beta_1} \int_{\underline{z}}^{\overline{z}}\left[\left(\frac{z}{z_e}\right)^{-\beta 1}-\left(\frac{z_e}{z}\right)^{\beta_2}\right] dz .
\end{aligned}$$

Since $z_e < \underline{z}$, $\beta_1 < 0$ and $\beta_2 > 1$, $(z/z_e)^{-\beta 1} > 1 > (z_e/z)^{\beta_2}$ for $z \in [\underline{z}, \overline{z}]$. Thus, the numerator of H_1 is positive so that $H_1 > 0$. ■

Proof of Proposition 3:

Equity value prior to reorganization is equal to the sum of the present value of the claims prior to reorganization and the present value of the claims after reorganization. That is,

$$\begin{aligned}
e_x(z, z_x, b, \underline{b}; p) &= (1-\tau) E^z\left[\int_0^{T_{z_x}} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right]+E^z\left[e^{-(r+\eta) T_{z_x}} e(z_x, \underline{b}; p)\right] \\
&= (1-\tau) E^z\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right]+e(z_x, \underline{b}; p) E^z\left[e^{-(r+\eta) T_{z_x}}\right] \\
& \quad -(1-\tau) E^z\left[\int_{T_{z_x}}^{\infty} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right] \\
&= (1-\tau) E^z\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right]+E^z\left[e^{-(r+\eta) T_{z_x}}\right] \\
& \quad \times\left\{e(z_x, \underline{b}; p)-(1-\tau) E^{z_x}\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right]\right\} .
\end{aligned}$$

Substituting the expressions,

$$E^z\left[e^{-(r+\eta) T_{z_x}}\right]=\left(\frac{z}{z_x}\right)^{\vartheta},$$

and

$$E^z\left[\int_0^{\infty} e^{-(r+\eta)t}(\pi(z_t; p)-b) dt\right]=\Pi(z; p)-\frac{b}{r+\eta},$$

into the above equation yields (43). Equation (44) follows from a similar argument. ■

Proof of Proposition 4:

The constraint (45) can be rewritten as

$$\frac{\underline{b}}{r+\eta} + \left(\alpha A(z_d(\underline{b});p) - \frac{\underline{b}}{r+\eta}\right)\left(\frac{z_x}{z_d(\underline{b})}\right)^{\vartheta} = \frac{b}{r+\eta} + \left(\alpha A(z_d(b);p) - \frac{b}{r+\eta}\right)\left(\frac{z_x}{z_d(b)}\right)^{\vartheta}.$$

Substituting the expression for $A(\cdot)$ in (21) yields

$$b - \underline{b} = (z_x)^{\vartheta}\frac{\gamma - \vartheta(1-\alpha(1-\tau))}{\vartheta - \gamma}\left[\underline{b}z_d(\underline{b})^{-\vartheta} - bz_d(b)^{-\vartheta}\right].$$

Simplifying yields

$$z_x = \left[\frac{\vartheta - \gamma}{\gamma - \vartheta(1-\alpha(1-\tau))}\frac{b - \underline{b}}{\underline{b}z_d(\underline{b})^{-\vartheta} - bz_d(b)^{-\vartheta}}\right]^{1/\vartheta} \tag{54}$$

I first show that z_x is increasing in $\underline{b}$. Differentiating z_x with respect to $\underline{b}$ and using the expression for z_d (23) yields

$$\frac{\partial z_x}{\partial \underline{b}} = \frac{-1}{\vartheta} z_x \frac{\psi(\underline{b}) + (b-\underline{b})\psi'(\underline{b})}{\psi(\underline{b})(b-\underline{b})}$$

where

$$\psi(\underline{b}) \equiv \underline{b}z_d(\underline{b})^{-\vartheta} - bz_d(b)^{-\vartheta} < 0.$$

Therefore, noting $\vartheta < 0$, to show $\frac{\partial z_x}{\partial \underline{b}} > 0$, one only needs to show that

$$\psi(\underline{b}) + (b-\underline{b})\psi'(\underline{b}) = \underline{b}z_d(\underline{b})^{-\vartheta} - bz_d(b)^{-\vartheta} + (b-\underline{b})z_d(\underline{b})^{-\vartheta}\frac{\gamma(\underline{b}+c_f) - \vartheta\underline{b}}{\gamma(\underline{b}+c_f)} < 0.$$

or

$$b\left[1 - \left(\frac{z_d(b)}{z_d(\underline{b})}\right)^{-\vartheta}\right] - \frac{\vartheta\underline{b}\,(b-\underline{b})}{\gamma(\underline{b}+c_f)} < 0,$$

Let $\Phi(\underline{b})$ be the expression on the LHS of the above inequality. It is easy to show that $\Phi(b) = 0$ and $\Phi(0) < 0$. Thus, the above inequality follows from the fact that $\Phi'(\underline{b}) > 0$ for $\underline{b} \in [0, b)$.

Next, I show that equity value prior to reorganization is decreasing in $\underline{b}$. Substituting z_x into (54) and differentiating with respective $\underline{b}$, one can show that $\partial e_x(z_t, z_x, b, \underline{b}; p)/\partial \underline{b} < 0$. Thus, equity value is maximized for as low coupon as possible. Since $\frac{\partial z_x}{\partial \underline{b}} > 0$, it is optimal to delay the debt exchange offer as long as possible. But I have made the assumption that $z_x \geq z_d(b;p)$. Thus, the constraint is binding, i.e., $z_x = z_d(b;p)$.

Finally, substituting $z_x = z_d(b; p)$ and the expression for $z_d(b; p)$, (23), into (54) yield (46).

$$\Phi'(\underline{b}) = -b\vartheta \left(\frac{b + c_f}{\underline{b} + c_f}\right)^{-\vartheta} + \frac{\vartheta}{\gamma}\underline{b} - \frac{\vartheta}{\gamma}\frac{(b - \underline{b})\, c_f}{\underline{b} + c_f} > 0.$$

■

References

Andrade, G. and S.N. Kaplan, 1998, How costly is financial (not economic) distress? evidence from highly leveraged transactions that became distressed, *Journal of Finance* 53, 1443-1493.

Baker, M. and J. Wurgler, 2002, Market timing and capital structure, *Journal of Finance* 57, 1-32.

Barclay, M.J., E. Morellec and C.W. Jr. Smith, 2002, On the debt capacity of growth options, forthcoming in *Journal of Business*.

Black, F. and J. M. Scholes, 1973, The pricing of options and corporate liabilities, *Journal of Political Economy* 81, 637-659.

Bolton, P., and D. Scharfstein, 1990, A theory of predation based on agency problems in financial contracting, *American Economic Review* 80, 93-106.

Bradley, M., G. Jarrell, and E.H. Kim, 1984, On the existence of an optimal capital structure, *Journal of Finance* 39, 857-878.

Brady, B. and R. Bos, 2002, *Record Defaults in 2001: The Result of Poor Credit Quality and a Weak Economy*, Standard & Poor's.

Brander, J.A., and T.R. Lewis, 1986, Oligopoly and financial structure: the limited liability effect, *American Economic Review* 76, 956-970.

Brander, J.A., and T.R. Lewis, 1988, Bankruptcy costs and the theory of oligopoly, *Canadian Journal of Economics* 21, 221-243.

Brennan, M.J. and E.S. Schwartz, 1984, Optimal financial policy and firm valuation, *Journal of Finance* 39, 593-607.

Caballero and E.M.A. Engel, 1999, Explaining investment dynamics in U.S. Manufacturing: A generalized (S,s) approach, *Econometrica* 67, 783-826.

Caves, R.E., 1998, Industrial organization and new findings on the turnover and mobility of firms, *Journal of Economic Literature* 36, 1947-1982.

Chevalier, J.A., 1995a, Capital structure and product-market competition: empirical evidence from the supermarket industry, *American Economic Review* 85, 415-435.

Chevalier, J.A., 1995b, Do LBO supermarkets charge more? an empirical analysis of the effects of LBOs on supermarket pricing, *Journal of Finance* 50, 1095-1112.

Cooley, T.F. and V. Quadrini, 2001, Financial markets and firm dynamics, *American Economic Review* 91, 1286-1310.

Dasgupta, S. and S. Titman, 1998, Pricing strategy and financial policy, *Review of Financial Studies* 11, 705-737.

Dixit, A., 1989, Entry and exit decisions under uncertainty, *Journal of Political Economy*, 97, 620-638.

Dixit, A. and R. Pindyck, 1994, *Investment Under Uncertainty*, Princeton University Press, Princeton, NJ.

Duffie, D., and D. Lando, 2001, Term Structures of Credit Spreads with Incomplete Accounting Information, *Econometrica* 69, 633-664.

Dunne, T., M.J. Roberts, and L. Samuelson, 1988, Patterns of firm entry and exit in U.S. manufacturing industries, *Rand Journal of Economics* 19, 495-515.

Ericson, R. and A. Pakes, 1995, Markov-perfect industry dynamics: A framework for empirical work, *Review of Economic Studies* 62, 53-82.

Fan, H. and S.M. Sundaresan, 2000, Debt valuation, renegotiation, and optimal dividend policy, *Review of Financial Studies* 13, 1057-1099.

Feldman, M. and C. Gilles, 1985, An expository note on individual risk without aggregate uncertainty, *Journal of Economic Theory* 35, 26-32.

François, P. and E. Morellec, 2002, Capital structure and asset prices: Some effects of bankruptcy procedures, *Journal of Business,* forthcoming.

Franks, J.R., and W.N. Torous, 1994, A comparison of financial recontracting in distressed exchanges and Chapter 11 reorganization, *Journal of Financial Economics* 35, 349-370.

Fries, S., M. Miller and W. Perraudin, 1997, Debt in industry equilibrium, *Review of Financial Studies* 10, 39-67.

Gilson, S.C., J. Kose, and L.H. Lang, 1990, Troubled debt restructuring: an empirical study of private reorganization of firms in default, *Journal of Financial Economics* 27, 315-353.

Goldstein R., N. Ju and H. Leland, 2001, An EBIT-based model of dynamic capital structure, *Journal of Business* 74, 483-512.

Gomes, J.F., 2001, Financing investment, *American Economic Review* 91, 1263-1285.

Graham, J.R., 1996, Proxies for the corporate marginal tax rate, *Journal of Financial Economics* 42, 187-221.

Graham, J.R., 2000, How big are the tax benefits of debt?, *Journal of Finance* 55, 1901-1941.

Harris, M., and A. Raviv, 1991, The theory of capital structure, *Journal of Finance* 46, 297-355.

Harrison, M.J. and D.M. Kreps, 1979, Martingales and arbitrage in multiperiod securities markets, *Journal of Economic Theory* 20, 381-408.

Hopenhayn, H., 1992a, Entry, exit, and firm dynamics in long run equilibrium, *Econometrica* 60, 1127-1150.

Hopenhayn, H., 1992b, Exit, selection, and the value of firms, *Journal of Economic Dynamics and Control* 16, 621-653.

Hopenhayn, H. and R. Rogerson, 1993, Job turnover and policy evaluation: a general equilibrium analysis, *Journal of Political Economy* 101, 915-938.

Jensen, M., 1986, Agency costs of free cash flow, corporate finance and takeovers, *American Economic Review* 76, 323-329.

Jensen, M.C., and W. Meckling, 1976, Theory of the firm: managerial behavior, agency costs, and ownership structure, *Journal of Financial Economics* 4, 305-360.

Jovanovic, B., 1982, Selection and the evolution of industry, *Econometrica* 50, 649-670.

Ju, N., R. Parrino, A.M. Poteshman, and M.S. Weisbach, 2003, Horses and Rabbits? Optimal dynamic capital structure from shareholder and manager perspectives, Working paper, University of Texas at Austin.

Judd, K.L., 1985, The law of large numbers with a continuum of IID random variables, *Journal of Economic Theory* 35, 19-25,

Karatzas, I., and S. Shreve, 1991, *Brownian Motion and Stochastic Calculus.* Second Edition. Springer Verlag, Berlin.

Kovenock, D. and G.M. Phillips, 1997, Capital structure and product market behavior: an examination of plant exit and investment decisions, *Review of Financial Studies* 10, 767-803.

Kraus, A. and R.H. Litzenberger, 1973, A state-preference model of optimal financial leverage, *Journal of Finance* 33, 911-922.

Kydland, F.E. and E.C. Prescott, 1982, Time to build and aggregate fluctuations, *Econometrica* 50, 1345-1370.

Lambrecht, B.M., 2001, The impact of debt financing on entry and exit in a duopoly, *Review of Financial Studies* 14, 765-804.

Lang, L., E. Ofek, R.M. Stulz, 1996, Leverage, investment, and firm growth, *Journal of Financial Economics* 40, 3-29.

Leahy, J.V., 1993, Investment in competitive equilibrium: the optimality of myopic behavior, *Quarterly Journal of Economics* 108, 1105-1133.

Leland, H.E., 1994, Corporate debt value, bond covenants and optimal capital structure, *Journal of Finance* 49, 1213-1252.

Leland, H.E., 1998, Agency costs, risk management, and capital structure, *Journal of Finance* 4, 1213-1243.

Leland, H.E., and K.B. Toft, 1996, Optimal capital structure, endogenous bankruptcy, and the term structure of credit spreads, *Journal of Finance* 51, 987-1019.

Lindenberg, E.B. and S.A. Ross, 1981, Tobin's q ratio and industrial organization, *Journal of Business* 54, 1-32.

Mackay, P. and G.M. Phillips, 2001, Is there an optimal industry capital structure, Working paper, University of Maryland.

Maksimovic, V., 1990, Capital structure in repeated oligopolies, *Rand Journal of Economics* 19, 389-407.

Maksimovic, V., and Phillips, 1998, Asset efficiency and reallocation decisions of bankrupt firms, *Journal of Finance* 53, 1495-1532.

Maksimovic, V., and J. Zechner, 1991, Debt, agency costs, and industry equilibrium, *Journal of Finance* 46, 1619-1643.

Mauer, D.C., and A.J. Triantis, 1994, Interactions of corporate financing and investment decisions: a dynamic framework, *Journal of Finance* 49, 1253-1277.

Mella-Barral, P., 1995, Optimal debt exchange offers, Working paper, London School of Business.

Mella-Barral, P., 1999, The dynamics of default and debt reorganization, *Review of Financial Studies* 12, 535-578.

Mella-Barral, P., and W.R.M. Perraudin, 1997, Strategic debt service, *Journal of Finance 52, 531-556.*

Mello, A.S., and J.E. Parsons, 1992, Measuring the agency costs of debt, *Journal of Finance* 47, 1887-1904.

Merton, R., 1974, On the pricing of corporate debt: The risk structure of interest rate, *Journal of Finance* 29, 449-469.

Miao, J., 2002, Stationary equilibria of economies with a continuum of consumers, Working paper, University of Rochester.

Miao, J. and E. Morellec, 2003, Capital structure, credit risk, and macroeconomic conditions, Working paper, University of Rochester.

Modigliani, F., and M. Miller, 1958, The cost of capital, corporation finance and the theory of investment, *American Economic Review* 48, 267-297.

Modigliani, F., and M. Miller, 1963, Corporate income taxes and the cost of capital: A correction, *American Economic Review* 53, 433-443.

Morellec, E., 2001, Asset liquidity, capital structure and secured debt, *Journal of Financial Economics* 61, 173-206.

Morellec, E., 2002, Can managerial discretion explain observed leverage ratios?, forthcoming in *Review of Financial Studies.*

Myers, S.C., 1977, The determinants of corporate borrowing, *Journal of Financial Economics* 37, 189-238.

Orr, D., 1978, The determinants of entry: A study of the Canadian manufacturing industries, *Review of Economics and Statistics* 56, 58-66.

Parrino, R. and M.S. Weisbach, 1999, Measuring investment distortions arising from stockholder-bondholder conflicts, *Journal of Financial Economics* 53, 3-42

Phillips, G.M., 1995, Increased debt and industry product markets: an empirical analysis, *Journal of Financial Economics* 37, 189-238.

Poitevin, M., 1989, Financial signalling and the deep-pocket argument, *Rand Journal of Economics* 20, 26-40.

Rajan, R., and L. Zingales, 1995, What do we know about capital structure? some evidence from international data, *Journal of Finance* 50, 1421-1467.

Titman, S. and S. Tsyplakov, 2002, A dynamic model of optimal capital structure, Working paper, University of Texas at Austin.

Titman, S. and R. Wessels, 1988, The determinants of capital structure choice, *Journal of Finance* 43, 1-19.

Welch, I., 2004, Stock Returns and Capital Structure, forthcoming in *Journal of Political Economy.*

Williams, J.T., 1995, Financial and industrial structure with agency, *Review of Financial Studies* 8, 431-474.

Zingales, L., 1998, Survival of the fittest or the fattest? exit and financing in the trucking industry, *Journal of Finance* 53, 905-938.

Table 1. Base Case Parameter Values

	Parameter	Value
Returns to scale	ν	0.4
Depreciation rate	δ	10%
Shock drift	μ_z	0.75%
Shock volatility	σ_z	15%
Riskless rate	r	5.22%
Corporate tax rate	τ	34%
Bankruptcy cost	$1 - \alpha$	20%
Poisson death	η	4%
Entry cost	c_e	78.35
Entry distribution	$\underline{z}$	2.5
Entry distribution	$\overline{z}$	3.5
Price elasticity	ε	0.75
Fixed cost	c_f	0

Table 2. Comparative Statics for Selected Parameter Values.

The parameter values for the base case model are given in Table 1. Comparative statics is based on the base case model. When performing simulations for the entry cost, I set the fixed cost $c_f = 5$.

	Industry Output	Average Leverage	Turnover Rate	Exit Threshold	Optimal Coupon	Tax Advantage	Agency Cost
Base case	1	23.09	7.51	1.91	6.66	7.16	2.57
$\mu_z = 1.0\%$	1.03	17.50	7.29	1.92	6.62	5.46	1.80
$\mu_z = 1.5\%$	1.10	4.46	6.91	1.94	6.55	1.41	0.39
$\sigma_z = 10\%$	0.97	39.43	6.04	2.04	6.28	12.55	2.76
$\sigma_z = 20\%$	1.06	7.04	9.13	1.79	7.18	2.14	1.08
$\overline{z} = 4.0$	1.06	22.42	7.46	2.03	6.49	6.97	2.42
$\overline{z} = 4.5$	1.12	21.68	7.40	2.15	6.30	6.77	2.25
$\alpha = 95\%$	1.01	24.50	8.27	2.02	7.20	7.39	2.51
$\alpha = 90\%$	1.006	24.00	7.98	1.98	7.01	7.31	2.54
$\tau = 25\%$	1.04	20.43	7.12	1.84	5.96	4.63	1.74
$\tau = 40\%$	0.97	25.00	7.70	1.94	7.08	9.17	3.22
$c_f = 5$	0.82	16.64	9.37	2.15	7.77	5.23	1.77
$c_f = 10$	0.72	13.54	10.83	2.27	8.48	4.30	1.30
$c_e = 70$	0.85	16.16	9.55	2.16	6.94	5.08	1.70
$c_e = 100$	0.76	17.61	9.01	2.11	9.52	5.52	1.92

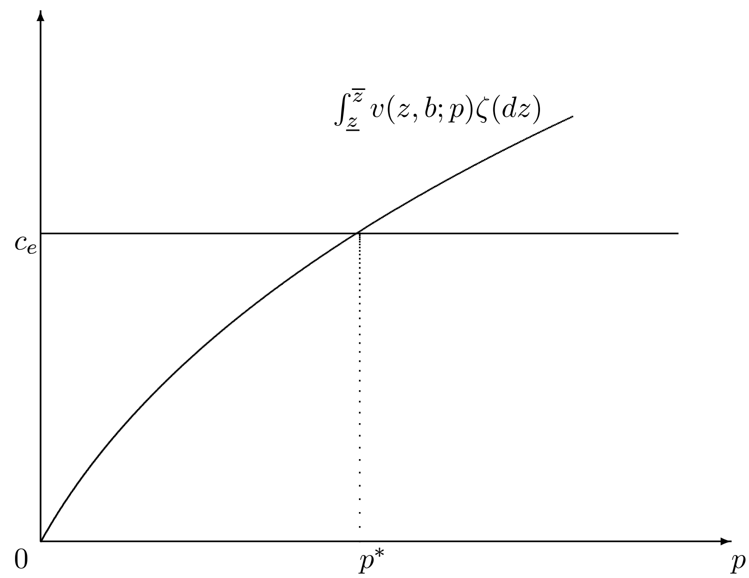

Figure 2: **The determination of the equilibrium output price p^*.**

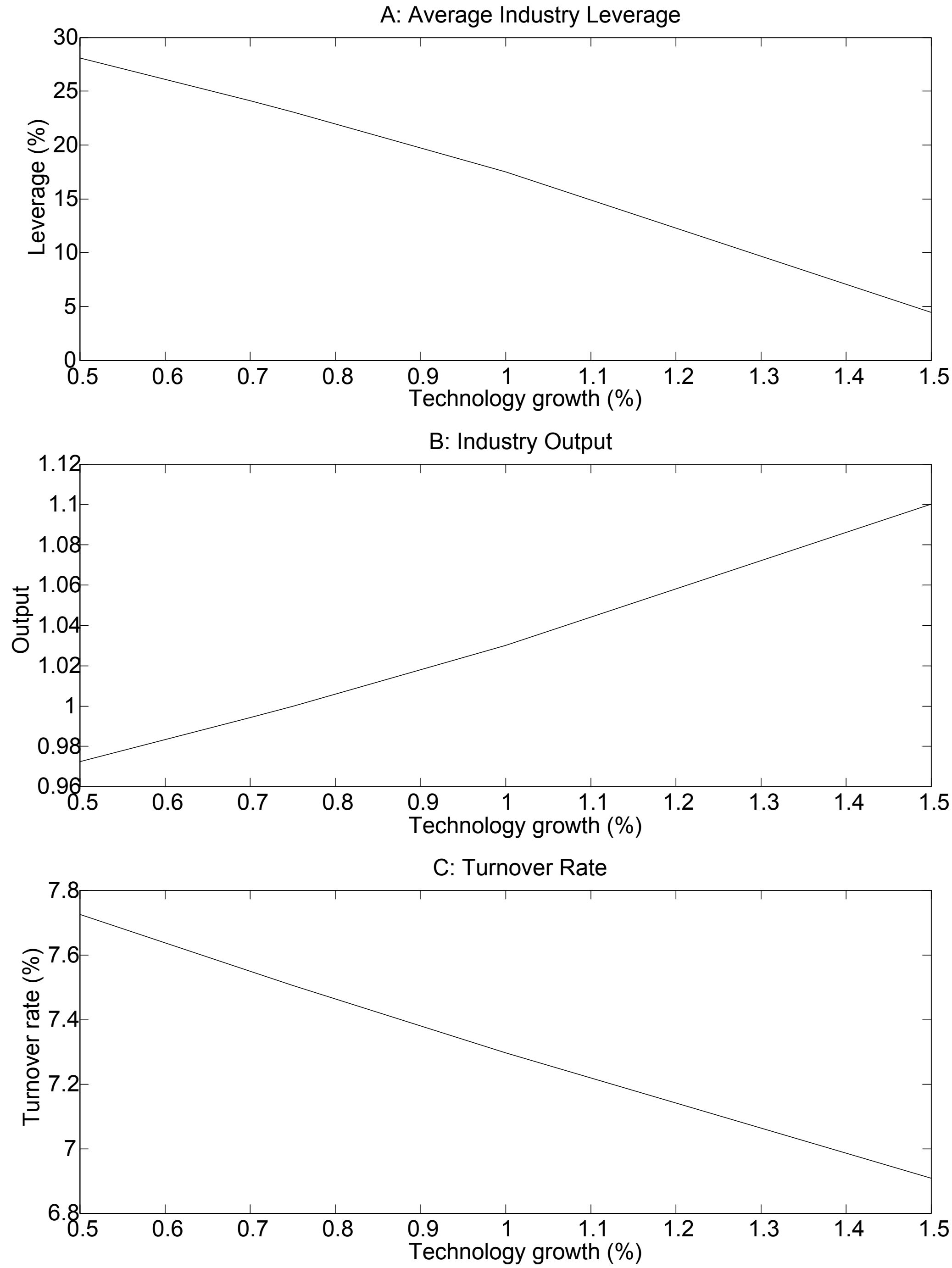

Figure 3: **The relation between technology growth, average industry leverage, industry output, and the turnover rate.** The technology growth μ_z varies over $[0.5\%, 1.5\%]$. All other parameter values are given in Table 1.

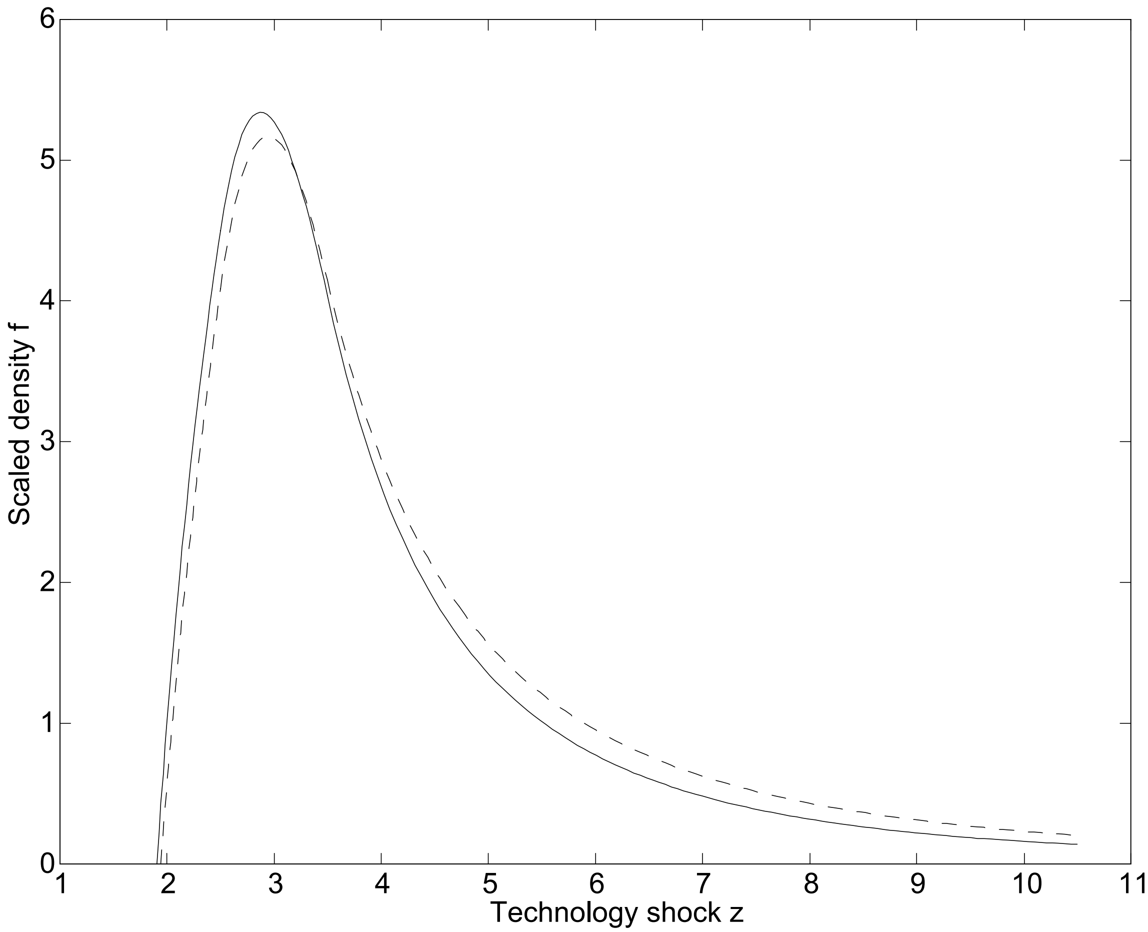

Figure 4: **The effect of an increase in growth of technology on the scaled density of firms.** The solid line is for the base case model. The dashed line is for $\mu_z = 1.5\%$. All other parameter values are given in Table 1.

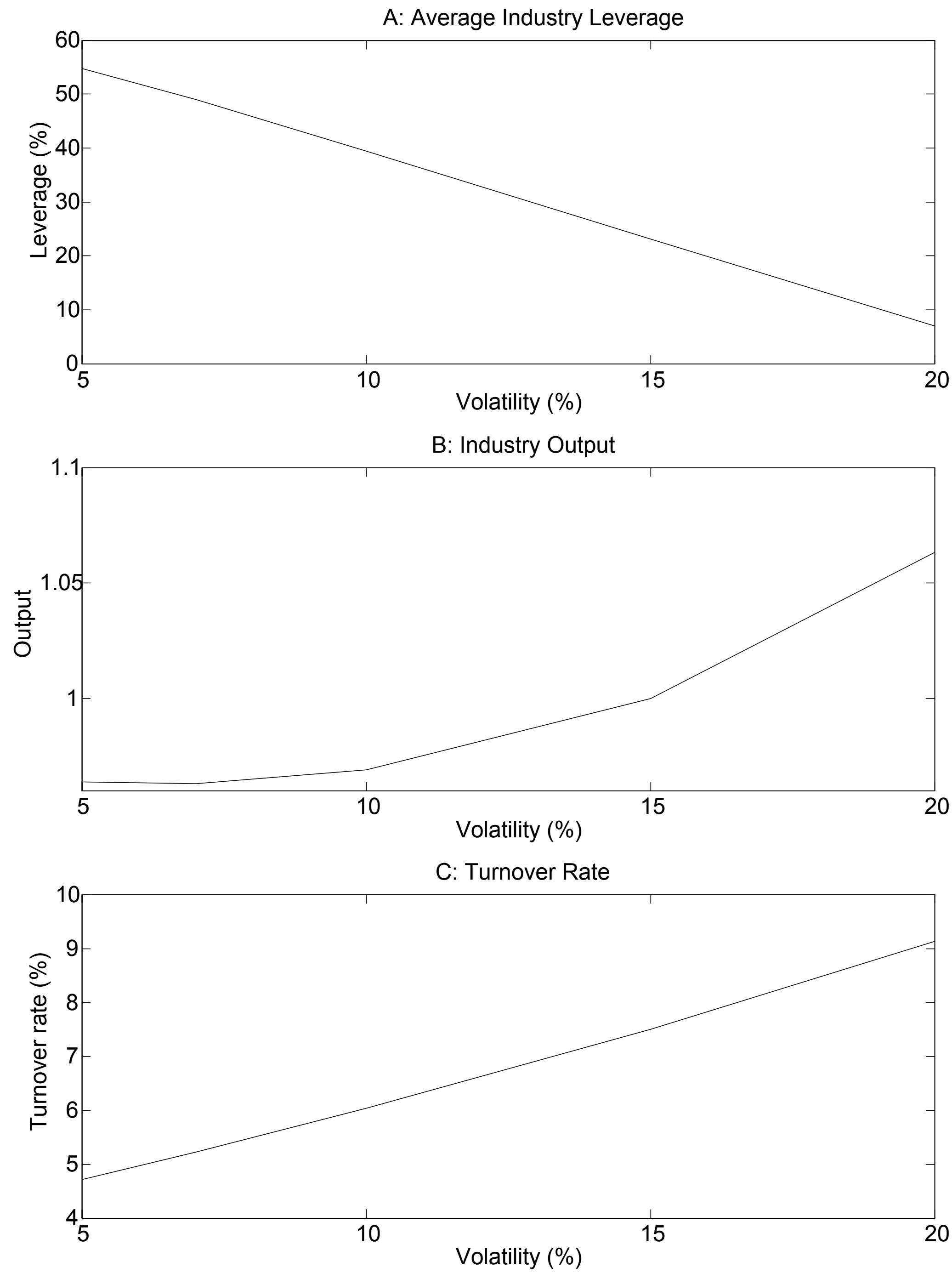

Figure 5: **The relation between technology volatility, average industry leverage, industry output, and the turnover rate.** The volatility parameter σ_z varies over $[5\%, 20\%]$. All other parameter values are given in Table 1.

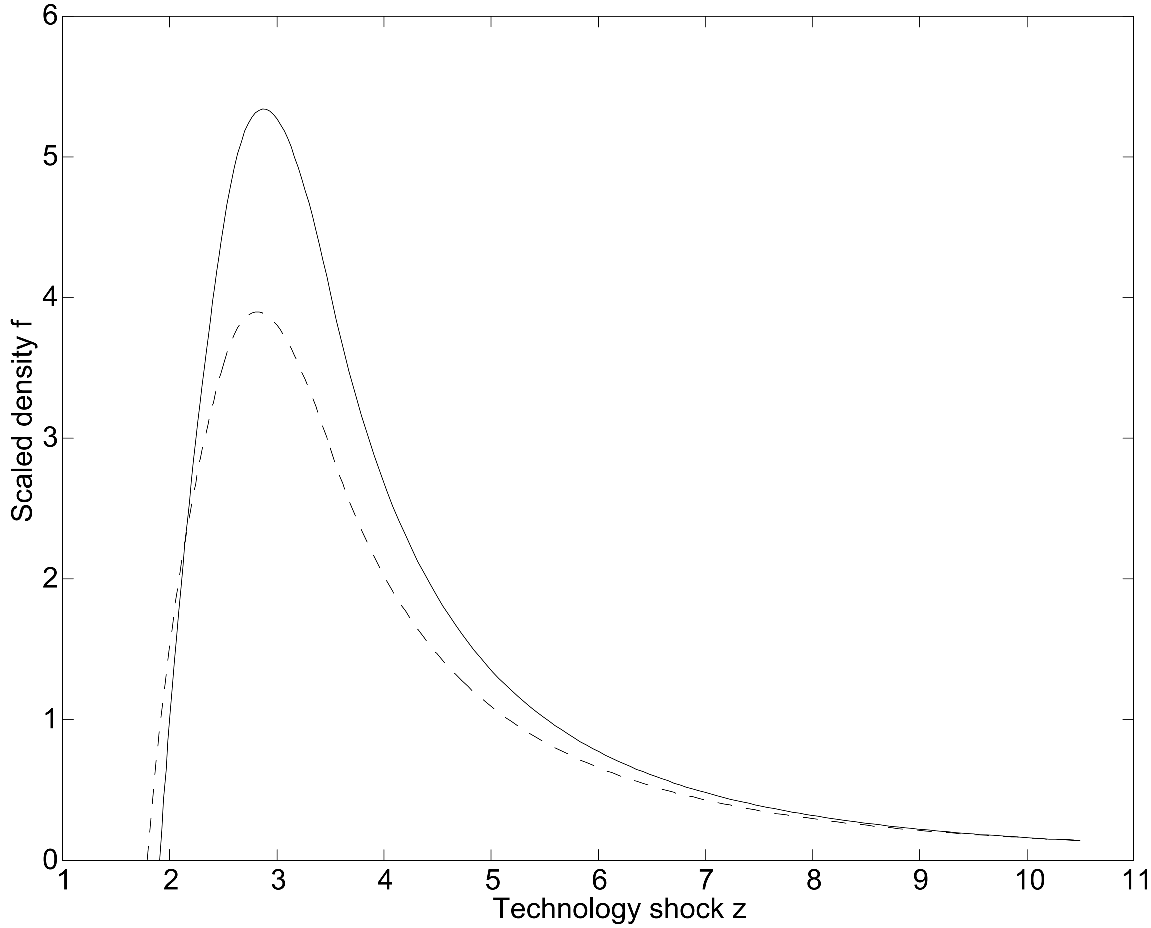

Figure 6: **The effect of an increase in risks of technology on the scaled density of firms.** The solid line is for the base case model. The dashed line is for $\sigma_z = 20\%$. All other parameter values are given in Table 1.

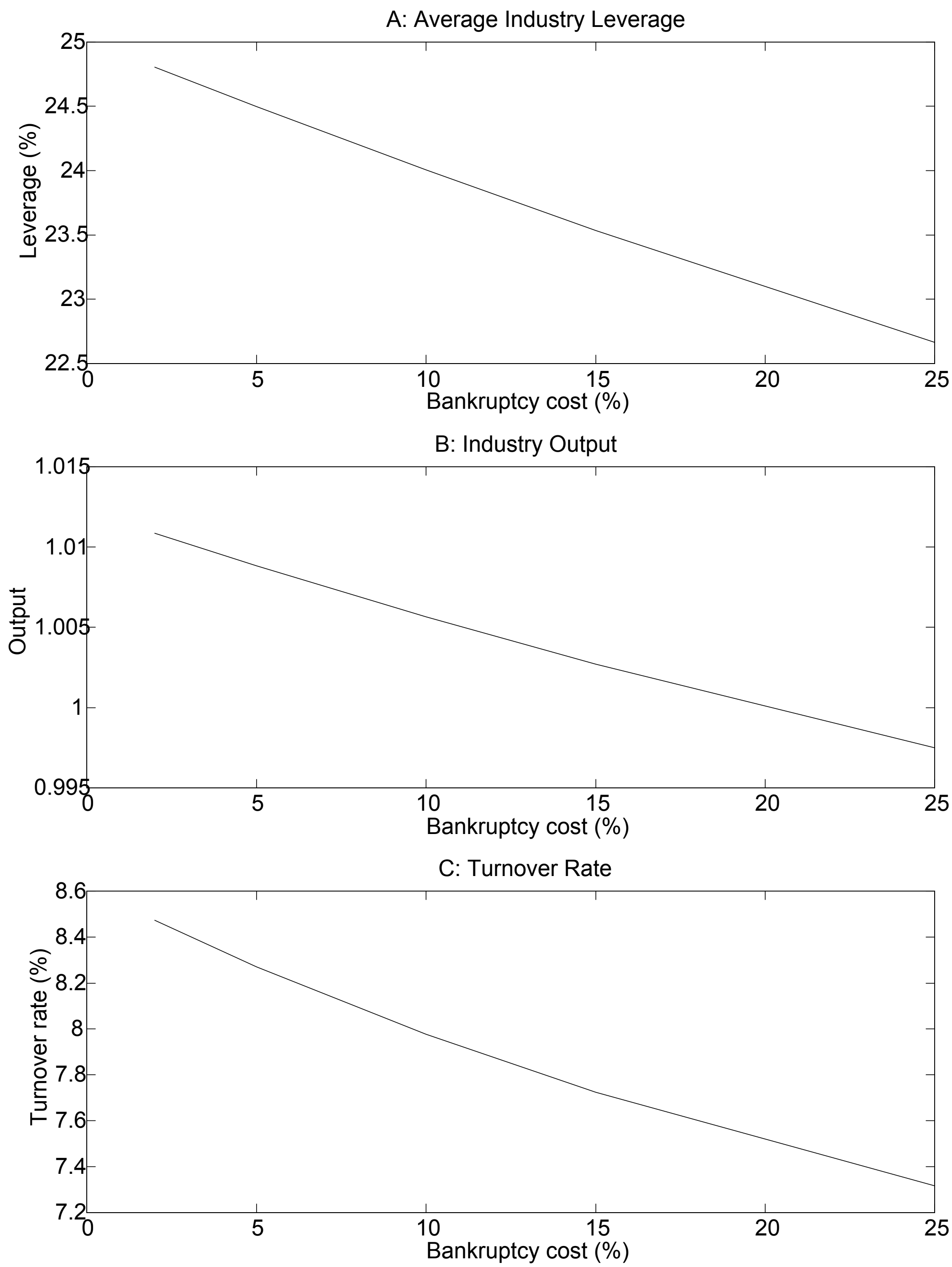

Figure 7: **The relation between bankruptcy cost, average industry leverage, industry output, and the turnover rate.** The bankruptcy cost parameter $1 - \alpha$ varies over $[2\%, 25\%]$. All other parameter values are given in Table 1.

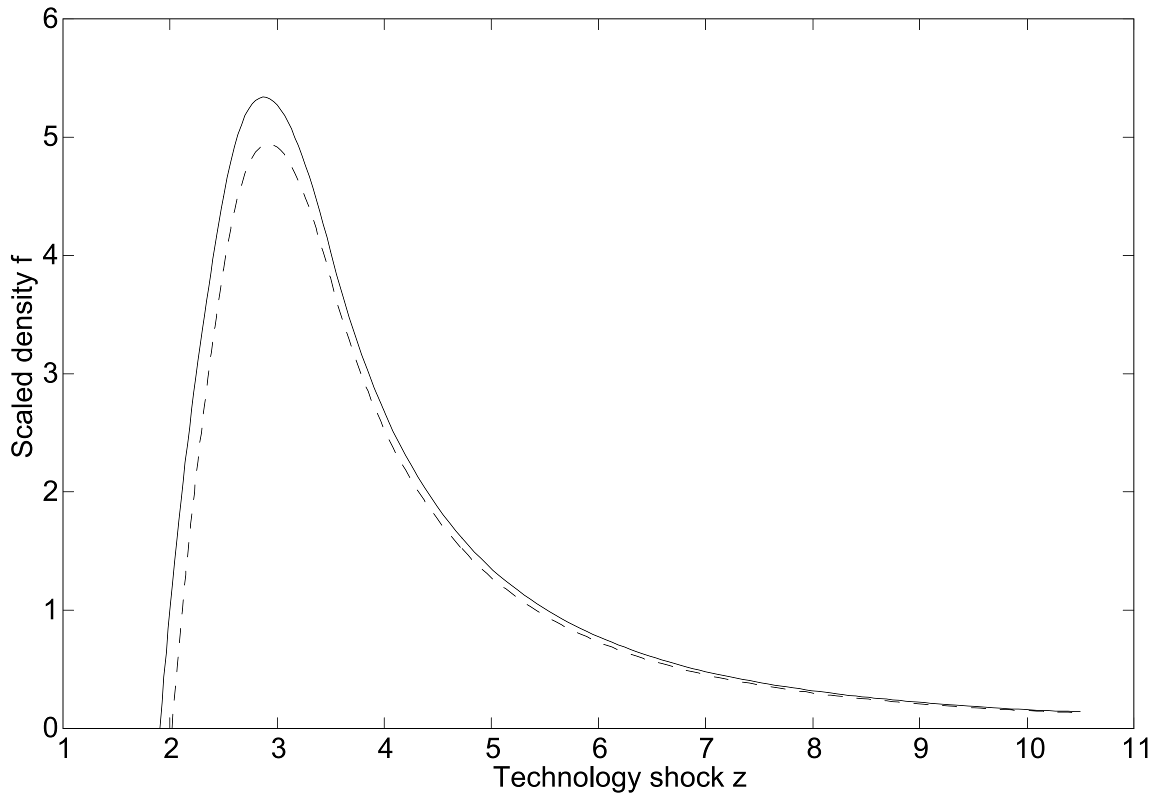

Figure 8: **The effect of an increase in bankruptcy cost on the scaled density of firms.** The solid line is for the base case model. The dashed line is for $\alpha = 95\%$. All other parameter values are given in Table 1.

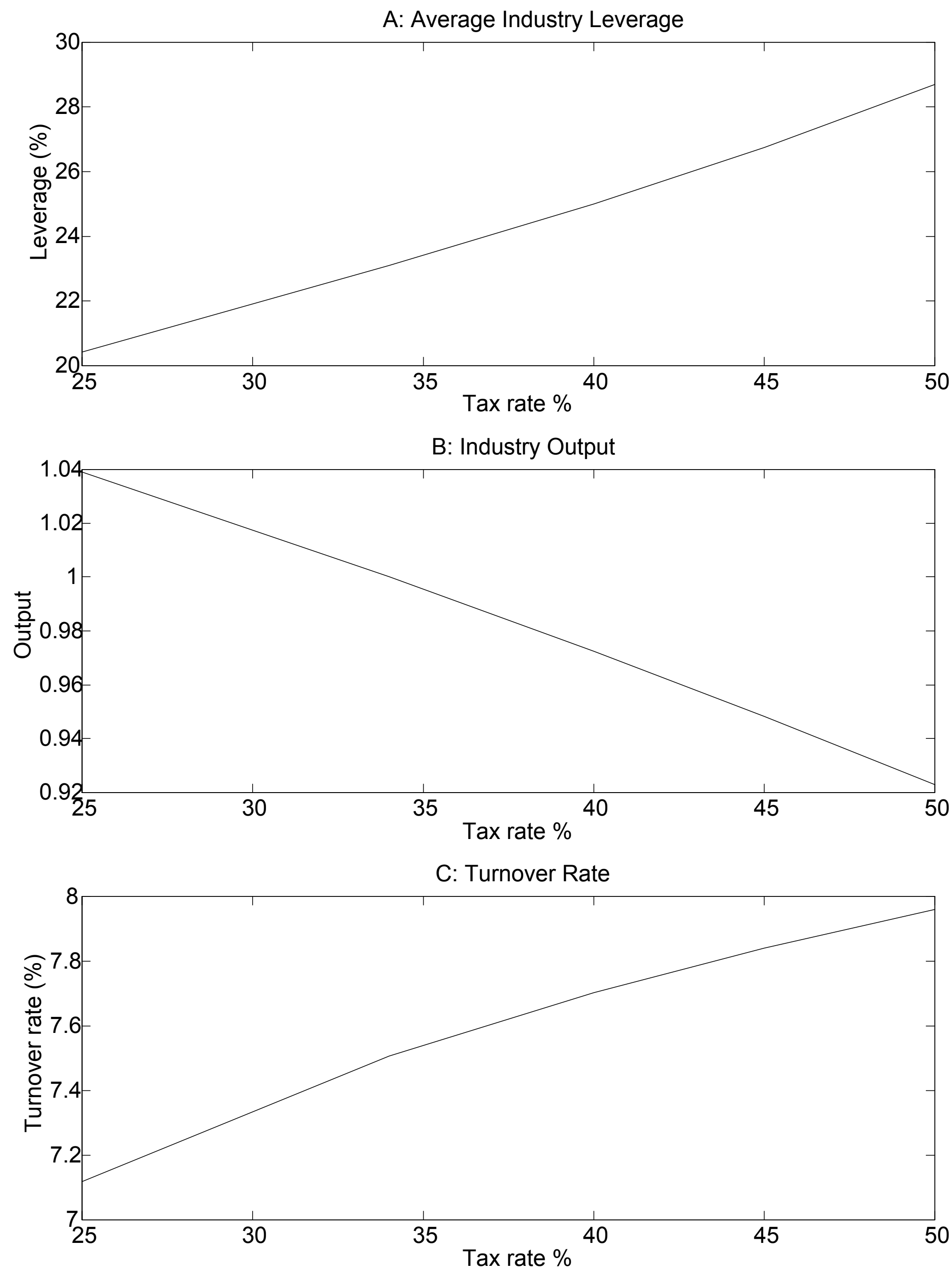

Figure 9: **The relation between the corporate tax rate, average industry leverage, industry output, and the turnover rate.** The tax rate parameter τ varies over $[20\%, 50\%]$. All other parameter values are given in Table 1.

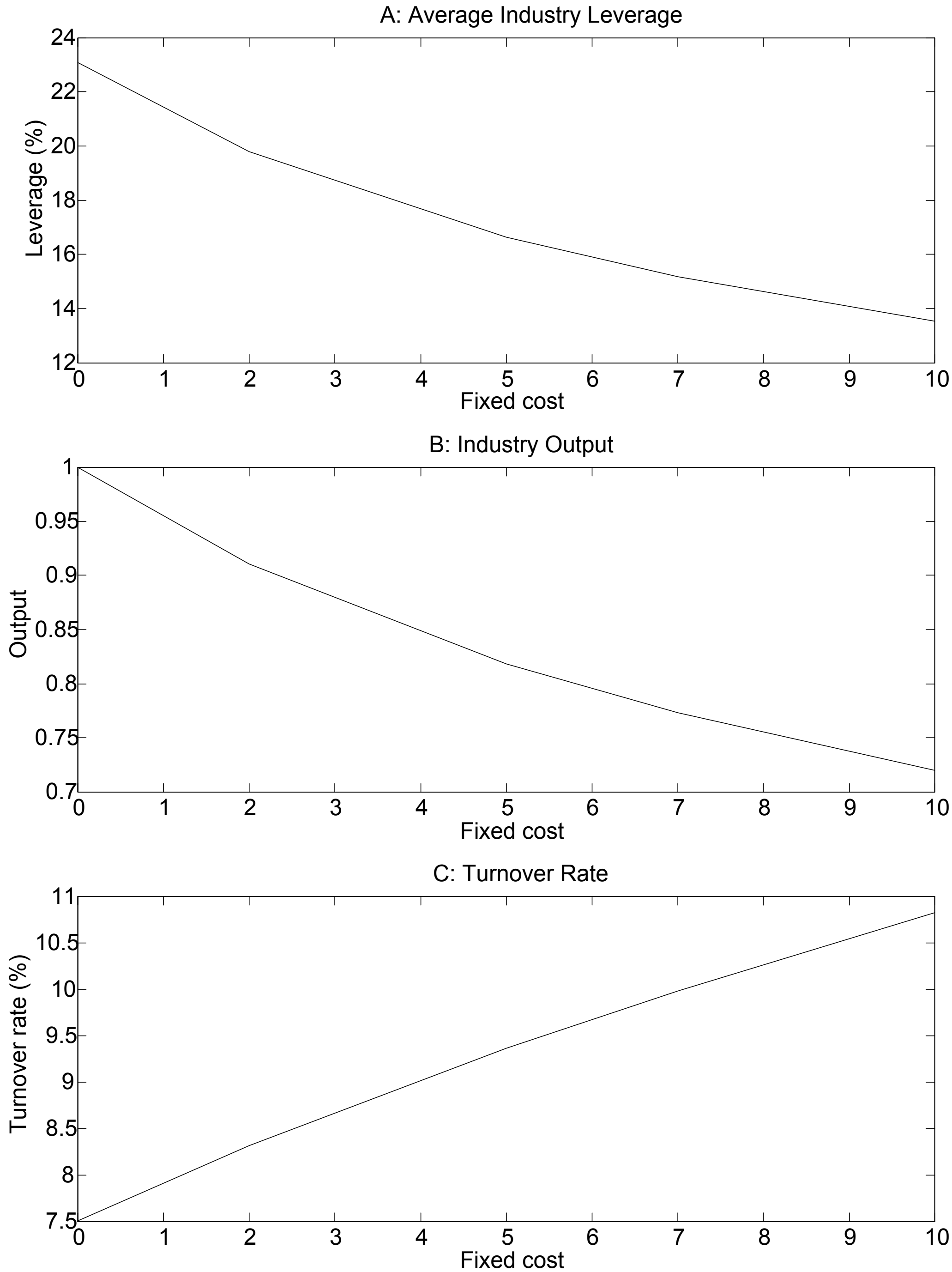

Figure 10: **The relation between the fixed cost, average industry leverage, industry output, and the turnover rate.** The fixed cost parameter c_f varies over $[0, 10]$. All other parameter values are given in Table 1.

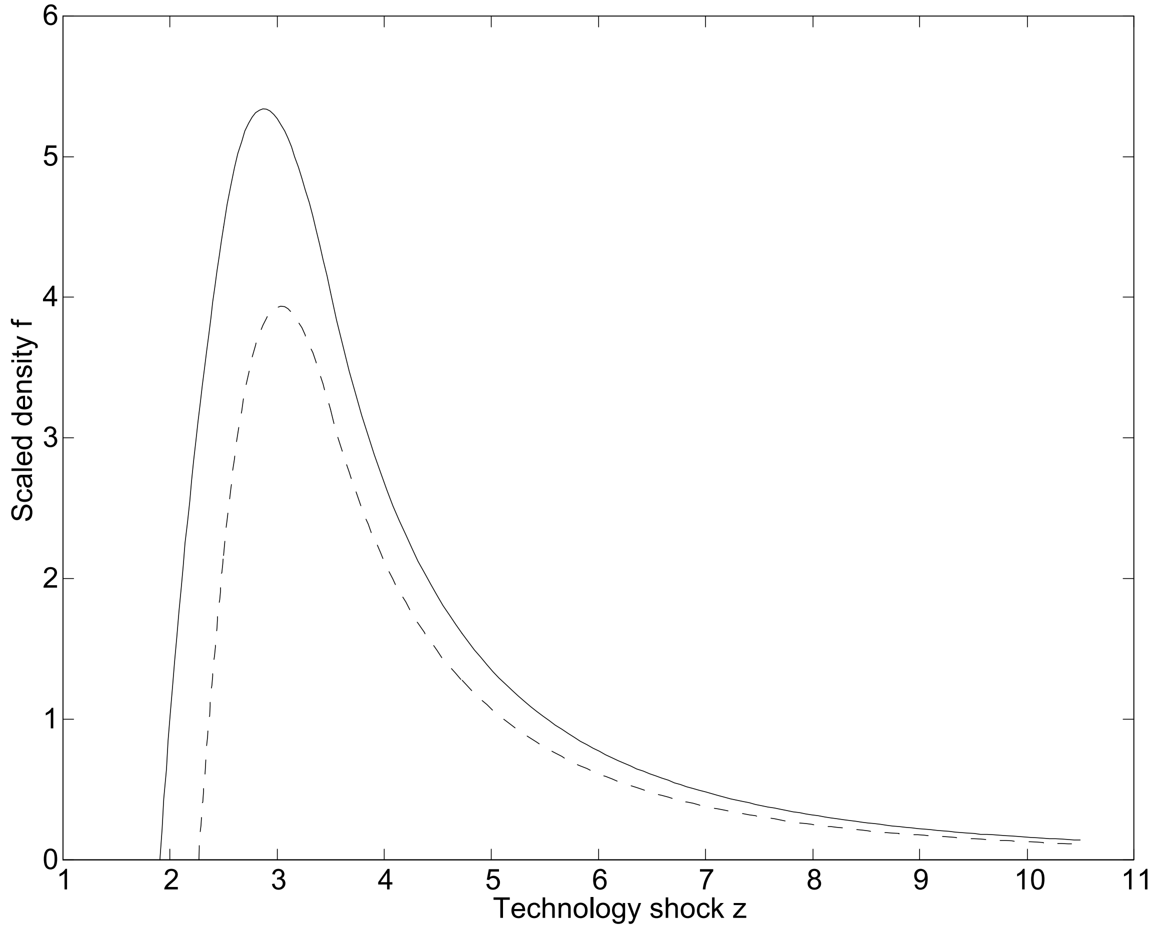

Figure 11: **The effect of an increase in the fixed cost on the scaled density of firms.** The solid line is for the base case model. The dashed line is for $c_f = 10$.

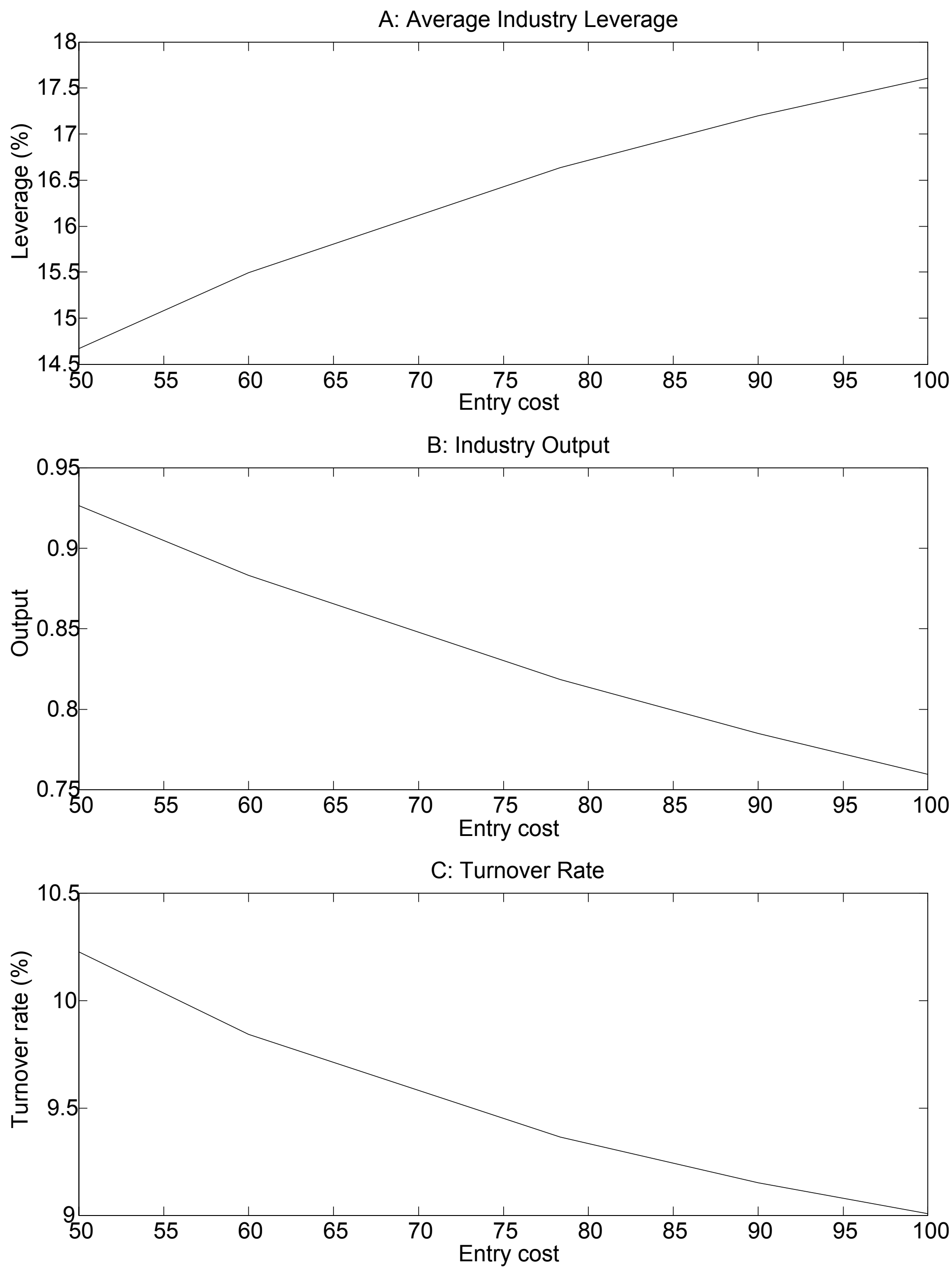

Figure 12: **The relation between the entry cost, average industry leverage, industry output, and the turnover rate.** The entry cost parameter c_e varies over $[60, 100]$. The fixed cost is set as $c_f = 5$. All other parameter values are given in Table 1.

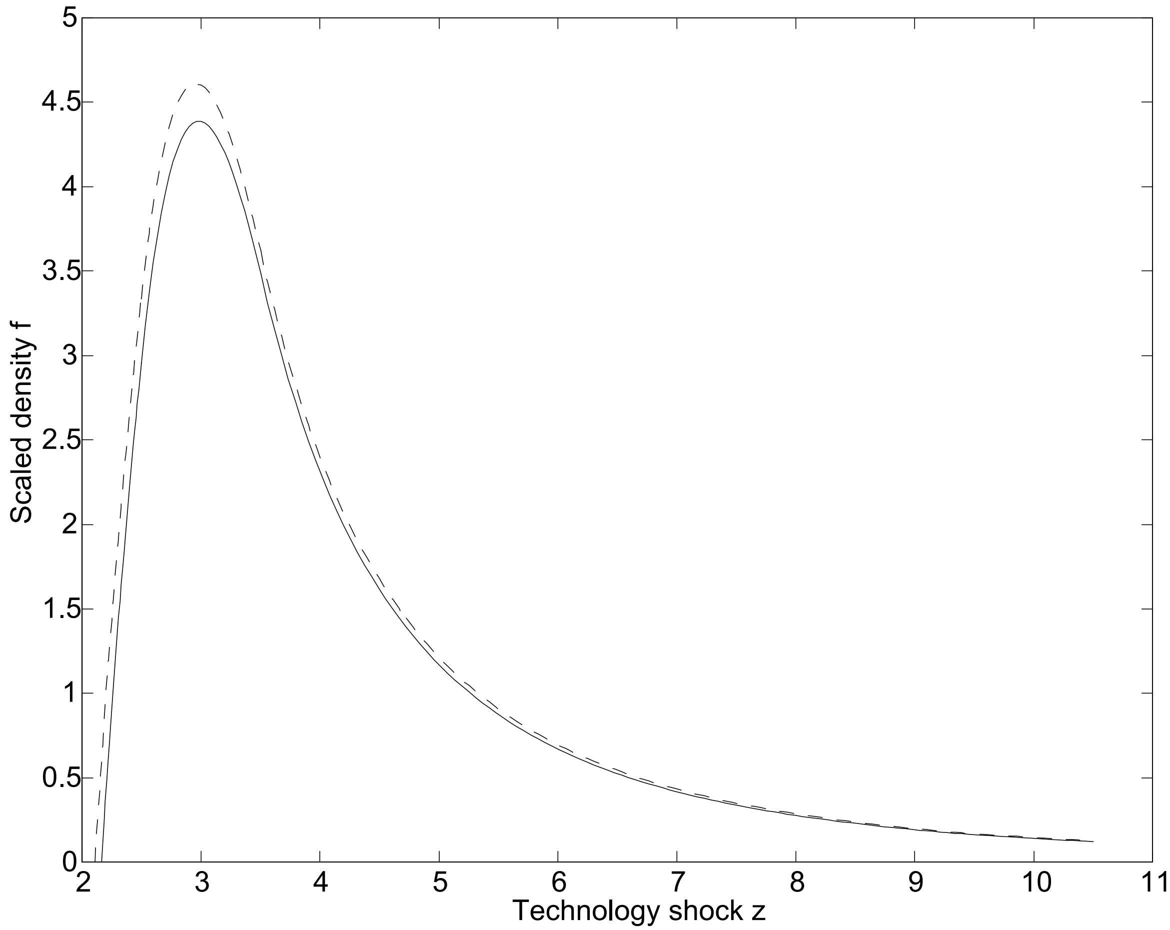

Figure 13: **The effect of an increase in the entry cost on the scaled density of firms.** The solid line is for $c_e = 70$. The dashed line is for $c_e = 100$. The fixed cost is set $c_f = 5$. All other parameter values are given in Table 1.