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THE UNIVERSITY OF WOLLONGONG  
DEPARTMENT OF ECONOMICS

A PARETO OPTIMAL CONDITION FOR BANKRUPTCY AND THE ROLE  
OF VARIATIONS IN AGGREGATE VARIABLES

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## ABSTRACT

This paper highlights the nexus of interactions among financial, industrial and macroeconomic factors determining the Pareto optimal date in which the firm's claimants stop collaborating and force the firm into bankruptcy. The derived bankruptcy condition summarises the effects of volatility of the aggregate consumer income and the overall price level which affect the firm's expected earnings, as well as the effects of depreciation, foregone interest on alternative usages of the loan extended to the firm and the level of risk perceived by the firm's claimants from continued collaboration. The subsequent econometric analysis focuses on the effects of the macroeconomic factors and shows that variations in the GNP and the GNP deflator affect the rate of bankruptcy in the U.S. significantly.

## I INTRODUCTION

The purpose of this paper is to develop a sufficient condition for bankruptcy within a framework which takes into account the nexus of interactions among financial, industrial and macroeconomic factors characterising the environment in which firms operate. These interactions appear to have attracted insufficient attention in previous studies in the field of bankruptcy. Special emphasis will be given in both the theoretical model and empirical analysis to the role of fluctuations in macroeconomic variables. The conceptual approach is influenced by the works of Bulow and Shoven (1978), Ang and Chua (1980) and White (1980) on the financial aspects; and by the works of Altman (1971) and Gordon (1971) on the macroeconomic aspects of bankruptcy. The analysis refers to a financially distressed firm operating in a oligopolistic industry and facing a random demand for its product due to fluctuations of aggregate consumer income and overall price level.

Though financial distress is a necessary condition for bankruptcy it is not a sufficient one. Bulow and Shoven (1978) argue that the criterion for bankruptcy is a positive gain to the coalition of the firm's claimants from immediate liquidation of the firm. Our analysis of the sufficient condition for bankruptcy adopts a similar approach in which the financially distressed firm is forced into bankruptcy if the potentially collaborating claimants perceive the net returns from continuation to be insufficient. It extends Bulow and Shoven's criterion by considering certain industrial structure and stochastic macroeconomic conditions affecting the firm's operation as well as the firm's claimants' risk attitude.

Along these lines the paper continues as follows. Section II develops a conceptual model which presents the firm claimants' evaluation of the net returns from continuation. Section III derives the Pareto optimal collaboration period and presents the condition for immediate liquidation of the financially distressed firm. Section IV provides an aggregate econometric analysis of the effects of variations of macroeconomic factors suggested in the preceding sections on the rate of bankruptcy in the United States of America.

## II CLAIMANTS' ATTITUDES AND DECISION ABOUT THE COLLABORATION PERIOD

This analysis considers a financially distressed firm facing two types of claimants: stockholder and bondholder (or other lender). Both claimants have unbiased expectations about the firm's future operating profits; but may differ with regard to the degree of absolute risk aversion, assessment of the level of uncertainty involved in the firm's future operation and priority on the firm's liquidation proceeds. The analysis assumes that the financial crisis arises from the firm's current inability to pay back the bond value which matures in the present period. In liquidation, bond principal claim and interest payments would be paid first. It assumes further that, unless sufficiently compensated, the bondholder is not willing to extend the bond maturity period and calls for an immediate liquidation; whereas the stockholder considers backing the firm as long as his expected returns from doing so sufficiently exceeds the costs of keeping the firm solvent. These costs consist of the compensation payments required for keeping the bondholder at least as well off as under immediate liquidation while extending the bond's maturity period. Of course, when these costs exceed the stockholder's expected returns from continuation, he would also prefer immediate liquidation. Thus, the derivation of the broader condition for bankruptcy considers the case where the net returns to the stockholder from continuation are nonnegative.

Our mathematical analysis uses the following symbols:

$T$	=	the firm's liquidation date;
$t$	=	a continuous time index, $0 \leq t \leq T$ ;
$S_0$	=	the sale value of the firm's present stock of productive assets (the plant);
$B_0$	=	the bond (or any other liabilities) claim against the firm at present;
$\pi(t)$	=	the firm's operating profit at $t$ ;
$\delta$	=	a fixed rate of depreciation of the firm's productive assets;
$i$	=	the bond interest rate;
$\gamma$	=	the bondholder subjective discounting rate;
$\rho$	=	the stockholder subjective discounting rate;
$C$	=	the present value of the compensation payment to the bondholder;

- $y_s(T)$  = the (random) present value of the net returns to the stockholder from continuation to T; and
- $y_b(T)$  = the (random) present value of the net returns to the bondholder from continuation to T.

The collaboration period  $(0, T)$  is determined by a consensus reached by the firm's claimants. It is assumed, for simplicity, that the sale price of the firm's productive assets remains the same over time and that there is no income tax. In this case the present expected value of the net returns to the stockholder from keeping the firm solvent during the time interval  $(0, T)$  is the discounted sum of the operating profits plus the remaining assets minus the liabilities at the end of the period and the compensation payment to the bondholder:

$$E[y_s(T)] = \int_0^T e^{-\rho t} E[\pi(t)] dt + S_0 e^{-\delta T} - B_0 e^{(i-\rho)T} - C. \quad (1)$$

The second term on the right hand side (RHS) of equation (1) is obtained from solving the motion equation of the firm's assets  $\dot{S}(t) = -\delta S(t)$  given the initial condition that  $S(0) = S_0$ . The third term on the RHS reflects the assumption that the interest on bond is accumulated and paid at T. The total debt is discounted by the stockholder subjective rate,  $\rho$ . Cash or other liquid assets are not included in equation 1. Their inclusion will not change the analysis considerably.

Correspondingly, the present value of the net returns to the bondholder from continuation are

$$y_b(T) = B_0 e^{(i-\gamma)T} + C. \quad (2)$$

As indicated by equation (1), the firm's operating profits are a key factor in the determination of the net returns to the stockholders from continuation, and hence, in the determination of the length of the collaboration period. The operating profits are affected by the economic environment in which the firm acts. We assume that the firm operates in an

oligopolistic industry consisting of  $N$  firms. Each firm is an expected profit maximiser which takes its competitors' supply as given (i.e., zero conjectural variation), and is characterised by an identical and constant marginal cost of production (i.e.,  $mc_n(q_n) = mc$  for all  $q_n$  and for every  $n = 1, \dots, N$ ).

We further assume that the inverse demand function for the industry's product consists of an isoelastic deterministic part and a stochastic part:

$$p(Q, Y, P) = Q^{-1/\xi} + \tilde{p}(P, Y). \quad (3)$$

where  $Q$  is the quantity demanded;  $\xi$  is the constant price elasticity of the deterministic part;  $Y$  and  $P$  are random variables with means  $\bar{Y}$  and  $\bar{P}$  and finite variances and covariance, denoting the aggregate consumer income and the overall price level of all the other goods, respectively. The stochastic part,  $\tilde{p}$ , is twice differentiable;  $\tilde{p}_Y$  is positive (negative) in the case of a normal (inferior) good and is equal to zero otherwise; and  $\tilde{p}_P$  is likely positive (negative) when the industry's product is rather substitute (complementary) to the rest of the goods and zero otherwise. In order to introduce the effects of variations in the macroeconomic factors  $Y$  and  $P$  on the bankruptcy decision we consider the second-order Taylor approximation of the inverse demand function at the means' point  $(\bar{Y}, \bar{P})$ :

$$\begin{aligned} p(Q, Y, P) \cong & Q^{-1/\xi} + \tilde{p}_Y(Y - \bar{Y}) + \tilde{p}_P(P - \bar{P}) + 0.5\tilde{p}_{YY}(Y - \bar{Y})^2 \\ & + 0.5\tilde{p}_{PP}(P - \bar{P})^2 + 0.5\tilde{p}_{YP}(Y - \bar{Y})(P - \bar{P}). \end{aligned} \quad (4)$$

The firm's decision problem

$$\max_{q_n} E\{[p(Q, Y, P) - mc]q_n\} \quad \text{s.t.} \quad Q = \sum_{n'=1}^N q_{n'} \quad (5)$$

leads to the Cournot-Nash expected product price

$$E(p^*) = \frac{1}{1 - 1/\xi N} \{mc - 0.5[\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)]\}. \quad (6)$$

(See the Appendix for a detailed solution of (5).)

The firm's expected profit is given in our case by

$$E[\pi(t)]_n = E[(p^* - mc) q_n^*] \quad (7)$$

and since  $q_n^*$  is a chosen quantity and all the firms have an identical production operation, then

$$\begin{aligned} E[\Pi(t)]_n &= \frac{Q^*}{N} [E(p^*) - mc] \\ &= \frac{mcQ^*}{N(\xi N - 1)} - \frac{0.5\xi Q^*}{\xi N - 1} [\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)] \end{aligned} \quad (8)$$

where  $Q^*$  is the industry volume of sales. *A priori*, the signs of the second derivatives of  $\tilde{p}$  and  $\text{cov}(Y, P)$  are unknown; and hence the effects of variations in the macroeconomic factors as well as the effects of the degree of industry concentration and price elasticity on the firm's expected operating profit are not clear. When  $[\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)]$  is negative (positive) the expected profit is greater (smaller) than that under certainty ( $mcQ^*/N(\xi N - 1)$ ). The discrepancy between the two decreases, however, with the level of the price elasticity and the number of producers.

It is assumed in the following that the expected profit remains the same. In view of this assumption, the substitution of equation 8 into equation 1 implies that the present expected value of the net returns to the stockholder from keeping the firm solvent during the period  $(0, T)$  is given by

$$\begin{aligned} E[y_s(T)] &= \frac{1}{\rho} \left\{ \frac{mcQ^*}{N(\xi N - 1)} - \frac{0.5\xi Q^*}{\xi N - 1} [\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)] \right\} (1 - e^{-\rho T}) \\ &\quad + S_0 e^{-\delta T} - B_0 e^{(i-\rho)T} - C. \end{aligned} \quad (9)$$



It is assumed that the firm claimants' expectations about their net returns from continuation are unbiased, but reflect increased uncertainty as the collaboration period expands. More specifically, the claimants' expected net returns from continuation to  $T$ ,  $y_s^e(T)$  and  $y_b^e(T)$ , are normally distributed with means which are equal to the theoretical values presented by equation 9 and equation 2, respectively; and with variances which are proportional to the collaboration's period,  $\sigma_s^2 T$  and  $\sigma_b^2 T$ , respectively. This is equivalent to saying that the expected net returns to the stockholder and bondholder from continuation to  $T$  can be approximated by Wiener processes (Brownian motion).

It is postulated that both claimants maximise expected utility and that their preferences on the expected net returns can be represented by utility functions which, in order to simplify the mathematical analysis, reflect constant degrees of absolute risk aversion  $R_s$  and  $R_b$ , respectively:

$$U_j(y_j^e(T)) = 1 - \exp\{-R_j y_j^e(T)\} \quad \text{for } j = s, b. \quad (10)$$

With this specification of  $U$ , the expected utility functions can be displayed as

$$E(U_j) = 1 - \int_{-\infty}^{\infty} \exp\{-R_j y_j^e(T)\} \phi_j(y_j^e(T)) dy_j^e(T) = 1 - m(-R_j) \quad \text{for } j = s, b \quad (11)$$

where  $m$  is the moment-generating function associated with the distribution of  $y_j^e(T)$ . Given that  $y_j^e(T)$  is normally distributed

$$E(U_j) = 1 - \exp\{-R_j E[y_j^e(T)] + 0.5 R_j^2 \sigma_j^2 T\} \quad \text{for } j = s, b. \quad (12)$$

Since the bondholder prefers an immediate liquidation (i.e.,  $T = 0$ ) upon continuation of the firm's operation, unless sufficiently compensated, the Pareto optimal collaboration period can be found by specifying the stockholder decision problem as follows

$$\max_T E[U_s(y_s^e(T))]$$

subject to

$$E[U_b(y_b^e(T))] = E[U_b(y_b^e(0))]. \quad (13)$$

The constraint reflects the compensation payment,  $C$ , required to keep the bondholder at least as well off as under immediate liquidation. In view of equations 12 and 2, this constraint can be rendered as

$$R_b[B_0 e^{(i-\gamma)T} + C] - 0.5 R_b^2 \sigma_b^2 T = R_b B_0. \quad (14)$$

Hence,

$$C = B_0[1 - e^{(i-\gamma)T}] + 0.5 R_b \sigma_b^2 T. \quad (15)$$

That is, in order to postpone the liquidation of the firm to  $T$ , the bondholder should be paid the foregone interest differential between his/her alternative financial activity and the firm's bond plus the cost of risk-bearings which is equal to the perceived level of uncertainty associated with his/her net returns from continuation to  $T$ , multiplied by his/her degree of absolute risk aversion.

Summing up, the Pareto optimal collaboration period can be found by solving the stockholder decision problem

$$\max_T \{1 - \exp\{-R_s E[y_s(T)] + 0.5 R_s^2 \sigma_s^2 T\}\} \quad (16)$$

where  $E[y_s(T)]$  is given by equation 9 and  $C$  by 15. Note that maximizing  $\{1 - \exp\{-R_s E[y_s(T)] + 0.5 R_s^2 \sigma_s^2 T\}\}$  is equivalent to maximising  $\{E[y_s(T)] - 0.5 R_s \sigma_s^2 T\}$ .

### III OPTIMAL COLLABORATION PERIOD AND THE CONDITION FOR IMMEDIATE LIQUIDATION

The Pareto optimal collaboration period ( $T^0$ ) should satisfy the necessary condition for maximum:

$$\left\{ \frac{mcQ^*}{N(\xi N-1)} - \frac{0.5\xi Q^*}{\xi N-1} [\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)] \right\} e^{-\rho T^0} - \delta S_0 e^{-\delta T^0} - (i - \rho) B_0 e^{(i-\rho)T^0} + (i-\gamma) B_0 e^{(i-\gamma)T^0} - 0.5R_b \sigma_b^2 - 0.5R_s \sigma_s^2 = 0. \quad (17)$$

Comparative statics and the second-order condition for maximum expected utility imply the following properties. First, the effect of the interest rate,  $i$ , on the collaboration period is not clear *a priori*. On the one hand, a higher interest rate on the firm's loans will discourage the stockholder since it increases the firm's liability accumulation. On the other hand, it enhances the attraction of the firm's bond to the bondholder *vis-a-vis* alternative financial activities and hence decreases the compensation payment required for the bondholder's collaboration.

Second, the effect of the stockholder's subjective discounting rate,  $\rho$ , on the collaboration period is not clear, *a priori*. On the one hand, it decreases the sum of the discounted expected firm's operating profits. On the other hand, it decreases the firm's discounted liabilities accumulated during the period of collaboration.

Third, the higher the bondholder's subjective discounting rate,  $\gamma$ , the shorter the collaboration period. This is due to the increase in the compensation payment required for obtaining the bondholder's collaboration.

Fourth, the greater the aversion of both the stockholder and the bondholder to risk, the shorter the collaboration period.

Fifth, the greater the variance of the aggregate variables  $Y$  and  $P$  and their covariance, the shorter (longer) the collaboration period provided that  $\tilde{p}_{YY}$ ,  $\tilde{p}_{PP}$  and  $\tilde{p}_{YP}$  are positive (negative).

The condition for immediate liquidation can be obtained by setting  $T^0$  equal to zero in equation 17:

$$\frac{mcQ^*}{N(\xi N-1)} - \frac{0.5\xi Q^*}{\xi N-1} [\tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YP} \text{cov}(Y, P)]$$

$$= \delta S_0 + (\gamma - \rho) B_0 + 0.5(R_b \sigma_b^2 + R_s \sigma_s^2). \quad (18)$$

This equation indicates that the financially distressed firm should be immediately forced into liquidation if the expected profit obtained from an infinitesimal continuation of the firm's operation (the terms on the left hand side) is just equal to the cost of doing so in terms of: depreciation of the firm's assets, foregone interest on alternative financial activity for the bondholder discounted by the stockholder rate of time preference, and the costs of risk-bearing for both claimants. Obviously, immediate liquidation is also optimal when the expected profit gained from infinitesimal continuation is outweighed by the costs. Note further that the probability of immediate liquidation increases (decreases) with the variances of the consumer aggregate income and the overall price level and their covariance, if  $\tilde{p}_{YY}$ ,  $\tilde{p}_{YP}$  and  $\tilde{p}_{PP}$  are positive (negative), respectively.

#### IV SOME AGGREGATE FINDINGS FOR THE UNITED STATES

In the lines of the above analytical discussion of the bankruptcy condition we conduct an econometric analysis of the bankruptcy rate in the post-World War II U.S.A. business sector. Due to the absence of data at the industry level our empirical study is restricted to the effects of the variations of the aggregate variables  $Y$  and  $P$ . The empirical analysis uses the real gross national product (RGNP) in 1972 billion dollars and the gross national product deflator (GNPD) as proxies for the aggregate consumer income and the overall price level, respectively. The variances and the covariance of these variables are computed with quarterly observations provided by Gordon (1984) for the period started  $J$  quarters before the end of the  $t$ -th year. Thereby measuring the variations in the macroeconomic factors before and during the time of bankruptcy as indicated by the following equations.

$$\text{Var}(Y_t) = \frac{1}{J} \sum_{j=0}^J (\text{RGNP}_{t-j} - \overline{\text{RGNP}})^2 \quad (19)$$

$$\text{Var} (P_t) = \frac{1}{J} \sum_{j=0}^J (\text{GNPD}_{t-j} - \overline{\text{GNPD}})^2 \quad (20)$$

$$\text{cov} (Y_t, P_t) = \frac{1}{J} \sum_{j=0}^J (\text{RGNP}_{t-j} - \overline{\text{RGNP}}) (\text{GNPD}_{t-j} - \overline{\text{GNPD}}) \quad (21)$$

where  $\overline{\text{RGNP}}$  and  $\overline{\text{GNPD}}$  are the averages of the real GNP and the GNP deflator, respectively, for the period started J quarters before the end of the t-th year.

The dependent variable, the rate of bankruptcies (ROB), is taken as the annual number of bankruptcies per 10,000 firms from *The Business Failure Record* (Dun and Bradstreet Inc., 1984). The sample base consists of time-series observations for the years 1947-1982 (i.e.,  $t = 1947, \dots, 1982$ ).

Best estimation results as regards goodness of fit and level of significance are obtained with a semilog specification and when J is set to be 16. The following equation summarises the ordinary least squares estimation results:

$$\begin{aligned} \exp(\text{ROB}_t) = & \underset{(1.70)}{0.2439} \times 10^{38} + \underset{(3.02)}{0.3245} \times 10^{35} \text{Var}(Y_t) \\ & + \underset{(7.43)}{0.1142} \times 10^{37} \text{Var}(P_t) - \underset{(5.01)}{0.4196} \times 10^{36} \text{cov}(Y_t, P_t) + \text{error}_t. \end{aligned} \quad (22)$$

The t-ratios are indicated by parentheses,  $R^2 = 0.678$ ,  $F = 19.61$  and the Durbin-Watson statistic is 1.48. It is found that the estimation results are very robust with regard to our choice of J within the interval  $12 \leq J \leq 24$ . They deteriorate significantly for either smaller or greater values of J. These results indicate that the variations of macroeconomic variables suggested by the theoretical analysis have a significant role in explaining business failure. The annual rate of bankruptcy in the U.S.A. increases with the variations of the GNP and the GNP deflator yet decreases with their covariation.

Lack of data on bankruptcy rate at the industry level prevents the application of the empirical analysis to various industries in order to test the sensitivity of the coefficients of the bankruptcy rate regression equation to demand elasticity, level of concentration and the nature of the industry's product.

### Appendix: Solution to the Firm Decision Problem

Given the second-order Taylor approximation of the inverse demand function, the firm's objective function can be rewritten as

$$\begin{aligned} \max_{q_n} E \{ [Q^{-1/\xi} + \tilde{p}_Y(Y - \bar{Y}) + \tilde{p}_P(P - \bar{P}) + 0.5 \tilde{p}_{YY}(Y - \bar{Y})^2 \\ + 0.5 \tilde{p}_{PP}(P - \bar{P})^2 + 0.5 \tilde{p}_{YP}(Y - \bar{Y})(P - \bar{P}) - mc] q_n \} \end{aligned} \quad (A.1)$$

Taking exception of the objective function and recalling that the choice variable  $q_n$  is deterministic and that  $E(Y - \bar{Y}) = E(P - \bar{P}) = 0$ , the objective function can be further written as

$$\max_{q_n} \{ Q^{-1/\xi} q_n + 0.5 [ \tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YPCOV}(Y,P) ] q_n - mc q_n \} \quad (A.2)$$

The first-order condition for maximum is

$$-(1/\xi) Q^{*-1/\xi} q_n^*/Q^* + Q^{*-1/\xi} - mc + 0.5 [ \tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{YY} \text{Var}(P) + \tilde{p}_{YPCOV}(Y,P) ] = 0 \quad (A.3)$$

and since  $Q^{*-1/\xi} = E(p^*)$  and  $q_n^*/Q^* = 1/N$  (all firms have identical production operation).

$$E(p^*) = \frac{1}{1 - 1/\xi N} \{ mc - 0.5 [ \tilde{p}_{YY} \text{Var}(Y) + \tilde{p}_{PP} \text{Var}(P) + \tilde{p}_{YPCOV}(Y,P) ] \}. \quad (A.4)$$

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