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Author(s): Moshe Kim and Vojislav Maksimovic
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Debt and Input Misallocation

MOSHE KIM and VOJISLAV MAKSIMOVIC*

ABSTRACT

We investigate a class of agency costs of debt that arise because debt financing affects the firm's incentives to use inputs efficiently. A methodology for estimating this class of costs is presented and applied to a major industry, air transport. Our results are consistent with agency models that predict a decrease in efficiency as the debt increases. A part of the loss of efficiency that we identify is attributable to the greater use by levered firms of inputs that can be monitored and are collateralizable.

THE CONFLICTS OF INTEREST that can arise between different classes of claimants to the firm's cash flow have been extensively studied in the financial literature. These conflicts are relevant because the firm's investment and financing decisions affect the value of the firm and redistribute wealth across the different classes of securities. If the decision making power belongs only to the holders of a specific class of securities, then the firm's investment policy may maximize the value of that security, and not maximize the total value of the firm. This insight has been used in the financial literature to analyze the effect of capital structure on a wide range of key non-financial policy variables from an agency theory perspective. Among the policy effects studied are the effects of leverage on the amount of risk the firm undertakes,[1] on its willingness to invest,[2] and on the firm's output in imperfectly competitive markets.[3] Contributions to this literature have identified financial structures, typically debt-equity ratios, that at the margin optimally trade-off agency costs, and the tax or strategic advantages of debt financing.

Despite the intuitive appeal of agency costs as a determinant of the firm's financial structure, and their seeming applicability to particular cases, such as the recent savings and loans scandal (e.g., *Business Week*, October 31, 1988), there is surprisingly little evidence on the magnitude of agency costs.[4] Indeed, as

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[1] This relationship was first discussed by Jensen and Meckling (1976). See also Green and Talmor (1984) and Williams (1987).

[2] See Myers (1977), John and Nachman (1985), and Heinkel and Zechner (1990).

[3] See Brander and Lewis (1986) and Maksimovic (1986).

[4] Several recent empirical studies have examined the general issue of estimating optimal financial structures, without attempting to quantify agency costs. They include Bradley, Jarrell, and Kim (1984), Auerbach (1985), Long and Malitz (1985), Spence (1985), Titman and Wessels (1988), and Fischer, Heinkel, and Zechner (1989).

Ross (1987, p. 334) has observed, the agency approach, as it has been developed in finance literature, "... fares poorly if judged by asking what it is that would be a counter observation or count as evidence against it" and that the phrase agency costs "... takes on more of the trappings of an incantation than an analytical tool." This lack of empirical verification is of concern because there are several reasons to believe that, despite their appeal, the agency costs associated with financing decisions are not significant in practice. First, managers may not act in the interests of any class of security holders, but in their own interest. Agency costs in such cases may not be directly related to the firm's financial structure.[5] Second, as argued by Haugen and Senbet (1981, 1988), the existence of complex financial securities may be enough, by itself, to eliminate the agency costs associated with any particular class of security, such as debt. Third, the functioning of the market for corporate control may effectively prevent the dissipation of value by any group. Fourth, Grossman and Hart (1982) and Jensen (1986) have provided alternative analyses of agency relationships in the corporation that emphasize the positive effect of indebtedness. Thus, the importance of agency problems most frequently analyzed in the literature to the firm's production decision is at present an open question.

One reason for disagreements on the significance of agency costs is that the underlying theoretical models have tended to focus on the effect of financial structures on the equityholders' incentives and have modeled the relationship between the changes in incentives and the firm's non-financial decisions in a very stylized manner. As a result of this, the theory has generated very few directly testable implications.[6] In this paper we focus on the effect of altered incentives on the firm's use of inputs. We restate the agency problem of debt in a setting that takes into account the firm's technology and yields testable implications concerning the effect of debt on the firm's input decisions. Our framework explicitly permits the cost of production to depend both on the intertemporal input mix chosen and on the quantity produced. We then demonstrate how agency costs can be estimated by specifying and econometrically estimating the cost functions of firms. This methodology is applied by directly estimating the magnitude of agency costs due to the misallocation of inputs in a major industry, passenger air transport. This industry has been selected because the cost structures of air carriers are well understood and because excellent firm specific data on input *quantities* and prices are available.

The agency theoretic analysis of the effect of financial structures on the firm's production decision is reviewed in Section I. Our framework, based on the standard agency paradigm, and the econometric model for estimating agency costs are presented in Section II. The data are described in Section III. Section IV discusses the stochastic specification, estimation and results. Section V presents a methodology for the estimation of the effect of debt financing on growth in productivity. Section VI concludes the paper.

[5] Fama (1980) discusses the effect of the labor market on managers' incentives to deviate from the value maximizing output.

[6] We do not analyze a related issue, the effect of agency on the firm's financial decisions, such as financial market transactions.

I. Financial Structure and Agency Costs of Debt

In this section we briefly review the two major approaches to modeling the relationship between financing and operating decisions and discuss some problems that arise in testing these models. We discuss both the predominant approach, described in Barnea, Haugen, and Senbet (1985) that suggests that leverage may reduce value and recent contributions that suggest that high levels of debt may improve efficiency.

The standard agency paradigm assumes that the firm's financing decision precedes investment and output decisions and that operating decisions are made by the equityholders or managers who maximize the value of equity. If the firm has no debt outstanding, the equityholders' optimal policy is to maximize the value of the firm. However, pre-existing debt alters the equityholders' incentives. As a result of these altered incentives the firm may not allocate resources so as to maximize the firm's value, thereby creating an agency cost of debt. In selecting its financial structure the firm's owners must therefore balance the advantages of debt financing, such as tax shields, against the costs which arise due to the altered incentives of the levered firm.

As noted in the above, two principal effects of debt on incentives have been identified in the standard paradigm. First, as Jensen and Meckling (1976) demonstrated, a levered firm's equityholders have an incentive to increase the firm's risk, thereby increasing the debtholders' exposure, even when the additional risk is associated with a lower net present value of future cash flows. Second, as Myers (1977) showed, as the firm's leverage increases, equityholders have an incentive to under-invest in positively valued projects such as the maintenance of plant and equipment. This occurs because part of the benefits of new investment accrue to bondholders, whereas the equityholders, directly or indirectly, bear the costs of investment. Both these effects may increase the firm's expected cost of producing a given level of output.

Higher production costs may also arise from contractual attempts to resolve costly conflicts of interest created by the firm's financing decision. This effect can occur if the firm's inputs differ in liquidation value and hence in their usefulness as collateral. The firm's creditors can take advantage of these differences to link the availability of financing to the use of inputs that have a high salvage value, as with secured debt or leasing. Any deviation from the efficient input mix that results from this link is an agency cost of debt financing.

A closely related inefficiency may occur if the use of some inputs can be monitored, whereas others are difficult to observe. In this case debt financing may be tied to the use of inputs that can be monitored. This serves two purposes. First, it enables creditors to verify directly that funds are being used to provide inputs of the requisite quality and are not being diverted. Second, the marginal product of the remaining inputs may change as the quantity of the verifiable inputs is altered. Thus, it may be possible to increase the incentives of the equityholders to invest in unobservable inputs by altering the levels of the observed inputs, thereby reducing the overall agency costs of external financing. However, the input mix for which the equityholders' incentives are optimally aligned with those of the debtholders will not, in general, be the most efficient or "first-best."[7]

Both the standard agency paradigm and its extension to the case of contractually induced inefficiency in the employment of inputs suggest that the most significant conflict of interests in determining the firm's policy is that between different classes of investors. An alternative strand of analysis, developed in Grossman and Hart (1982) and Jensen (1986), posits that the more relevant conflict is that between the providers of capital and the firm's managers, who may wish to divert the firm's resources. However, the tendency to divert resources to unproductive uses diminishes with leverage when bankruptcy is costly to managers. Since the incentive effect of leverage is known to investors, debt is a credible commitment device by which managers bond themselves to act in the investors' interests. As a result, in some circumstances leverage may be associated with a higher degree of efficiency.

While the theoretical models discussed above suggest that there exists a relationship between the firm's financial structure and its production decisions, empirical confirmation of this link is not straightforward. The first difficulty is that the effect of changes in incentives can be manifested in diverse ways. In their analysis of under-investment and risk-shifting when the firm can vary its mix of inputs Kim and Maksimovic (1990) show that the interaction between financial and production variables will vary from case to case and will depend on the firm's technology. As a result, if the firm has a complex technology utilizing several inputs at different stages of the production cycle, then the agency costs of debt may not be characterized empirically as, for example, the simple under-investment problem described in the literature. Rather, agency costs of debt will be observed as a misallocation of inputs at different points in the production cycle, leading to over-investment in some inputs and under-investment in others.

The difficulties in testing for departures from efficiency are not confined to the analysis of the standard paradigm but apply more generally to all the models discussed above. Moreover, as firms in the same industry frequently face different prices for some inputs, the same leverage will create departures from efficiency that differ across firms. The differences will be compounded if optimal input mixes depend on firms' output levels. To avoid these confounding effects in estimating the economic significance of the class of agency costs that are of interest here, it is first necessary to specify a model of the firm's technology. This is discussed in the next section.

II. The Model

In this section we first outline a model, based on the standard agency paradigm, of the effect of debt on the production decisions of a firm facing uncertainty about the level of demand for its output. The outline is intended to make the assumptions of the standard paradigm more precise in order to motivate the stochastic specification below.[8] We then present the empirical model that will enable us to investigate econometrically whether debt financing affects the firm's

[7] For a discussion of the effect of contractually specified changes in the input mix on the equityholders incentives to provide unobservable inputs, see Bhattacharyya and Maksimovic (1990).

[8] For a more formal treatment of a similar model see Kim and Maksimovic (1990).

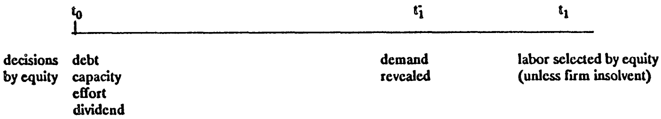

Figure 1. The sequence of events in the model of the firm.

use of inputs, and describe our tests for the effect of financial structure on the firms' costs and input demands. While our analysis directly follows from generalizing the standard paradigm to take into account the characteristics of the firm's technology, the resulting estimates will also provide evidence on the validity of the models that focus on conflicts between investors and managers.

A. The Firm's Input Decisions

We follow the standard paradigm in assuming that the most significant conflict of interests is between equityholders and debtholders. For our purposes it is important to analyze this conflict on incentives in a framework that allows for the possibility of input substitution and monitoring of some inputs by creditors. The simplest way to do this is in a two period model in which a firm, whose technology requires three inputs, is faced with random demand.

The time structure of the model is illustrated in Figure 1. At time t_0 the firm's equityholders make their financial structure choice, deciding how much debt to issue in order to profit from tax deductibility of this form of financing. At time t_0 they also determine the quantities of two inputs. The first, referred to as capital (or capacity), is observable and its purchase may be monitored by debtholders. We allow for the possibility that quantity of capacity is determined jointly with the time t_0 financing decision, as in lease financing. The second input purchased at time t_0, which we call managerial services (or effort), is not observed and cannot be monitored by creditors. Managerial services are here conceived broadly to include investment in intangibles such as planning, training, and internal monitoring systems that facilitate efficient production.[9] In the event that the proceeds from the sale of debt securities exceed the purchase price of the two inputs, the balance may be paid out as a dividend at this time t_0. If the cost of inputs exceeds the proceeds from the sale of debt, the excess is financed by equity.

Demand is revealed just before time t_1, at t_1^-. To complete the production process the firm must employ and pay for a third input, referred to as "labor."[10] Labor is combined with the other inputs at time t_1 to produce output which is then sold. If the equityholders do not choose to employ labor, they are deemed to have defaulted and ownership of the firm is transferred to the debtholders. In this case the debtholders then decide how much labor to employ and retain all profits. We assume that there are no deadweight costs of bankruptcy.[11]

[9] For a discussion of managerial inputs in the determination of financial structure, see Brander and Spencer (1989).

[10] The assumption of one input at time t_1 can be easily generalized to permit several inputs at each date.

[11] See the discussion of contractual arrangements to eliminate bankruptcy costs by Haugen and Senbet (1981) and Warner's (1977) finding that the direct costs of bankruptcy are low. The addition of bankruptcy costs would not alter the predictions of the model.

Given this structure of events, one can solve the model in the usual manner by backwards induction. Since there are no bankruptcy costs and all uncertainty is resolved before time t_1, the optimal quantity of labor to employ depends only on the realized market price and the quantities of the inputs supplied at time t_0. The quantity of labor employed at time t_1 does not depend on whether the equityholders have defaulted or not.

As soon as demand is revealed at time t_1^-, the equityholders can calculate the maximum revenue that they can realize by combining the optimal quantity of labor with the other inputs, capacity and effort, which are already in place. If the maximum revenue (after payment of labor) exceeds the debt obligation, then the equityholders proceed with the employment of labor. Otherwise they default.

At time t_0 the firms' owners select the face value of debt, D, the capacity level, and the amount of effort to maximize the value of equity. If at the optimal debt level there is a positive probability of bankruptcy, then the equityholders will not realize the payoffs from their investment in capital and effort in all states of the world. They will therefore make their investment decisions in capital and effort so as to maximize the value of equity, and not of the firm as a whole. As a result, the firm may not have the optimal mix of inputs at time t_1. The mix of inputs the firm employs will depend on the investment choices made by equity holders at time t_0 and on the pattern of substitutability and complementarity between inputs.

Since debtholders understand the equityholders' incentives, and the financial structure decision affects the input decisions at time t_0, the financial structure decision is equivalent to maximizing the total value of the firm. In maximizing value the owners trade-off an advantage of debt financing (for example, tax shields) with the associated agency costs. Since the firms in our sample all have debt claims outstanding we focus on the case where the optimum is at a positive debt level. Since investment in capacity can be monitored by debtholders, the equityholders may find it optimal to contractually commit to a specified level of investment in capacity at time t_0 through contractual provisions in the debt contract.[12] As an explicit solution is not required to estimate agency costs in our empirical model, we do not otherwise characterize the equilibrium financial structure.

Two effects of leverage in this framework are of importance for the analysis below. First, the level of capacity will in general deviate from the level of an all-equity firm despite the fact that capacity is observable. Second, the input decision at time t_0 will affect the optimal input mix at time t_1 (because the time t_1 input decision is conditioned on the choices made at time t_0), even though all uncertainty has been resolved by this time and no conflicts of interest remain. In general, with leverage the investment undertaken by equityholders will not minimize the unconditional expected cost of production at time t_1, thereby causing the firm to produce with diminished efficiency *even in those states in which it is solvent.* The magnitude of the efficiency losses depends on the opportunities for substitution of inputs over the production cycle.

[12] The terms of the commitment will take into account the incentives of equityholders to provide effort at time t_0. As a result, the amount of capacity acquired will in general not be the amount an all-equity firm would require.

These costs can be approximated by empirically estimating the effect of leverage on input decisions. In order to avoid econometric problems inherent in attempting to measure the after-tax user cost of capacity we proceed to do this in two stages. First, we focus on the time t_1 decision, taking the level of capacity as given. This allows us to analyze the effect of debt on the firm's usage of inputs purchased at time t_1 through its effect on investment in effort at time t_0. Second, we analyze whether debt causes capacity to deviate from the level chosen by an all-equity firm.

B. The Econometric Model

In analyzing the firm's incentives it is often convenient to model the firm's technology in terms of its production function. However, it is econometrically simpler to specify and test hypotheses about the firm's use of inputs using a cost function.[13] We can proceed in this way since it can be shown, using duality theory, that for every production function there exists a corresponding cost function.[14]

At time t_1, after the uncertainty has been resolved, the firm solves the following optimization program:

$$\min_x\{\mathbf{w}\cdot\mathbf{x} : y \leq f(k, e, \mathbf{x});\ e, k \in \operatorname{argmax}_{e,k} \mathscr{E}(S \mid S \geq 0)\}, \tag{1}$$

where k and e are the levels of capacity and effort chosen at time t_0, $\mathbf{x}$ is a vector of variable input quantities, $\mathbf{w}$ is a vector of unit prices of the variable inputs, y is the level of output, $\mathscr{E}$ is the expectation operator and S is the value of equity. Thus, the firm minimizes its variable costs $\mathbf{w}\cdot\mathbf{x}$ conditional on its technology ($y \leq f(\mathbf{x}, e, k)$), where k and e have been previously chosen to maximize the value of equity.[15]

The solution to the above optimization program, after taking into account that the level of effort is determined by the debt level, gives rise to the following (restricted) variable cost function,

$$VC = g(\mathbf{w}, k, y, D).$$

Since the quantities of capacity and debt, and not their prices, appear as arguments of the cost function this specification explicitly recognizes that, in our model, k and D have already been determined by the time the other, variable, inputs are chosen.[16] By construction the cost function yields the minimum cost of producing a given level of output as a function of the capacity level, variable input prices and lagged debt, regardless of how the firm determines its level of

[13] Recall that a cost function gives the firm's production costs as a function of input prices and quantity produced.

[14] Given the appropriate regularity conditions, both the production and cost functions provide the same information about the technology. For the regularity conditions see Shephard (1970) or Varian (1984).

[15] Since k and e are fixed at the time that the other inputs are determined the model is one of short-run temporary equilibrium in the sense of Berndt and Fuss (1986).

[16] Note that, as discussed in the previous section, the debt and capacity selected are in general affected by corporate taxes. However, since k and D are predetermined at the time the variable inputs are chosen, it is not necessary to take taxes into account explicitly in the variable cost function.

output. As a result, output can be treated as exogenous in the estimation of the cost function.

For our empirical work we have chosen the transcendental logarithmic (translog) specification of the cost function (Christensen, Jorgenson, and Lau (1973)).[17] The translog form allows the cost elasticity of debt and other relevant elasticities to be functions of all input prices, output levels, capacity, and the amount of debt and thus allows for a flexible description of the technology and the detection of the effect of debt in input demands.[18] We consider the following translog cost function:

$$\begin{aligned}\ln VC = {} & \alpha_0 + \textstyle\sum_T \rho_T + \sum_f \lambda_f + \alpha_y \ln y + \sum_j \beta_j \ln w_j \\ & + \beta_k \ln k + \gamma_D \ln D + \textstyle\sum_s \delta_s \ln \tau_s \\ & + \tfrac{1}{2}[A_{yy}(\ln y)^2 + A_{kk}(\ln k)^2 + \textstyle\sum_j \sum_i A_{ji} \ln w_j \ln w_i \\ & + A_{DD}(\ln D)^2 + \textstyle\sum_s \sum_l A_{sl} \ln \tau_s \ln \tau_l] \\ & + \textstyle\sum_j A_{jk} \ln w_j \ln k + \sum_j A_{yj} \ln y \ln w_j + A_{yD} \ln y \ln d \\ & + \textstyle\sum_j A_{jD} \ln w_j \ln D + A_{yk} \ln y \ln k \\ & + \textstyle\sum_s A_{sk} \ln \tau_s \ln k + \sum_s A_{sD} \ln \tau_s \ln D + \sum_s A_{sy} \ln \tau_s \ln y \\ & + \textstyle\sum_j \sum_s A_{js} \ln w_j \ln \tau_s + A_{kD} \ln k \ln D, \end{aligned} \tag{2}$$

where all exogenous variables above are normalized by their respective sample (arithmetic) means, the chosen point of approximation. In (2), α_0, ρ_T, λ_f, α_y, β_j, β_k, γ_d, δ_s, and the various A's are parameters to be estimated and y, w_j, k, D, and τ_s are the output, variable input prices, capacity, debt, and firm specific operating characteristics, respectively. The τ_s variables in (2) capture differences in firms' operating characteristics, such as, in the case of air carriers, the length of haul, points served, and load.[19] Since we use panel data consisting of a time series of a cross-section of firms, we introduce time and firm specific intercept shifts (effects). The time shifts ρ_T reflect variation in technology and other economic conditions through time for a given firm and the firm specific shifts λ_f reflect variation in technology across different firms.[20] The inclusion of these shift parameters precludes biases in the coefficients of the included explanatory variables that might arise from the exclusion of variables that are constant over time for a given firm.

The firm's demand for inputs depends directly on the characteristics of the cost function. We follow the literature in using input demand functions to

[17] The reason for choosing the translog over other functional forms such as the generalized Leontief (Diewert (1971)) or the CES-translog is the parsimonious parameterization of productivity growth with the translog. Also, this functional form has been used in practically all recent studies pertaining to U.S. air carriers.

[18] The translog functional form is said to be flexible in the sense that it has a sufficient number of free parameters to permit a second order approximation to an arbitrary twice continuously differentiable function with the appropriate theoretical properties.

[19] These operating characteristics were found to be of great importance in a well specified technology for air carriers (see Caves, Christensen, and Tretheway (1984)).

[20] This is the "within" and "between" method discussed in Mundlak (1978).

improve the efficiency of the estimation of the cost function. This can be done by estimating the cost function and input demand equations simultaneously and imposing the appropriate cross-equation restrictions. By Shephard's (1970) Lemma, the demand for an input x_j, is obtained by partially differentiating the cost function with respect to the variable input price $\partial VC/\partial w_j = x_j$. Partially differentiating the translog cost function (2) and using Shephard's Lemma, we obtain a set of n input demand equations in the form of cost shares:

$$\begin{aligned}\partial \ln VC/\partial \ln w_j &= (\partial VC/\partial w_j)(w_j/VC) = w_j x_j/C \equiv \Phi_j \\ &= \beta_j + \textstyle\sum_i A_{ji} \ln w_i + A_{yj} \ln y + A_{jD} \ln D + \sum_s A_{js} \ln \tau_s + A_{jk} \ln k \qquad (3)\end{aligned}$$

Using the fact that all cost share equations have to sum up to unity ($\sum_j^n \Phi_j = 1$) and the standard properties of cost functions,[21] the following linear restrictions can also be imposed on the cost and share equations:

$$\begin{aligned}&\textstyle\sum_j \beta_j = 1, \quad \sum_j A_{ji} = 0, \quad \sum_j A_{yj} = 0, \quad \sum_j A_{jD} = 0, \quad \sum_j A_{jk} = 0, \\ &\textstyle\sum_j A_{js} = 0, \quad A_{ij} = A_{ji}, \quad A_{sl} = A_{ls} \qquad (4)\end{aligned}$$

We examine the existence and economic significance of agency cost of debt in four ways. First, we test whether debt belongs in the specified cost function, using the likelihood ratio test, and interpret the signs of the relevant coefficients. The likelihood ratio is $\Omega = L_{\max(R)}/L_{\max(U)}$ for the restricted (R) and unrestricted (U) maximum values of the likelihood function L, and where the restricted version is the one with all coefficients involving debt restricted to take on zero values. The test statistic $-2 \log \Omega$ has an asymptotic distribution that is χ^2 with degrees of freedom equal to the number of constraints.

Using the parameter estimates of the cost function (2), we can calculate the demand for inputs and assess how debt affects them. The translog cost specification allows debt to affect variable costs in two ways. One way, which we term "neutral," is a pure shift of the cost function leaving variable input shares unchanged. If the debt has this effect, then the parameters γ_D and A_{DD} will be significantly different from zero. The other effect, which we refer to as "biased," is a shift in the level of costs that alters the equilibrium variable input shares (holding their prices constant) and is described by the parameters A_{jD}. If $A_{jD} < 0$ ($A_{jD} > 0$) the jth input's share of the variable costs is lowered (raised) as the level of debt increases.[22]

Second, we assess the economic significance of a misallocation of inputs due to leverage by computing the effect of changes in indebtedness on costs. The per period marginal agency costs of misallocation of inputs from a permanent increase in indebtedness is given by $\partial VC/\partial D$. As noted above, at the margin the firm will balance the costs of debt financing, such as agency costs, with the benefits, such as the interest tax shield. Thus, we expect the marginal cost of misallocation of inputs to be lower than or equal to the tax shield. We also compute another estimate of the effect of indebtedness, given by $\partial \ln VC/\partial \ln D$, the cost of elasticity

[21] That is, cost functions are linearly homogeneous in input prices and symmetric with respect to second partial derivatives in input prices and in the fixed input. These properties are discussed in Varian (1984).

[22] If $A_{jD} < 0$ ($A_{jD} > 0$) debt is defined to be jth input saving (using).

of debt, which measures the proportional change in costs caused by a proportional change in indebtedness.[23]

Third, since capacity has been chosen to maximize the value of equity given a pre-chosen debt level, the firm may employ capacity which diverges from long-run equilibrium configuration and thus departs from long-run cost minimization. Consequently, we calculate the implied long-run equilibrium costs (using the envelope condition) and assess the contribution of leverage to the departure of actual (short-run) costs from their long-run configuration.

A fourth measure of the effect of debt on the firm's costs is given by the calculation of total factor productivity. Total factor productivity measures how efficiently inputs are transformed into output, or analogously, how the average costs of producing various output levels change over time. To estimate the effect of changes in leverage on firms' efficiency we first develop a model of total factor productivity growth to isolate how changes in leverage have affected (changes in) cost efficiency over time. The model identifies the contributions of technical progress, non-constant returns to scale, and changes in firm specific operating characteristics, leverage, and capacity to total productivity growth in the sample period and thereby yields estimates of the relative effect of changes in leverage.

III. Data

Our data consist of annual observations on all trunk and local service air carriers from 1970 through 1981. Observations were deleted if the carrier experienced major strikes in excess of 25 days during the year.[24] The air carriers and the specific time periods included are listed in Table I. The non-financial data have been collected and employed in papers by Caves, Christensen, and Tretheway (1981, 1984) and are fully discussed in these papers. For completeness we summarize the variables and their calculation in this section.[25]

We employ three categories of variable inputs: labor, fuel, and materials. Labor price is formed as an index of fifteen categories of employees using the multilateral index procedures as in Caves, Christensen, and Diewert (1982).[26] Fuel price is

[23] All the measures of the effect of debt are calculated holding all the exogenous variables, including firm size (i.e., output), constant. Thus, it is unnecessary to standardize the debt level by any of the exogenous variables.

[24] Pan American and TWA were excluded as well because a very large part of their traffic is generated in international markets, thus facing different economic environments. These airlines also engage heavily in non-aviation activities, primarily hotel services, which makes a non-arbitrary separation of their leverage impossible.

[25] During this period air carriers were either wholly or substantially regulated. However, regulation did not take the form of limits on the allowed rate of return on assets and there is no reason to believe that it has any effect on our results.

[26] A multilateral factor for, say, labor is

$$\ln L_k - \ln L_l = \sum_i \left(\frac{w_{ik} + \bar{w}_i}{2}\right) \ln\left(\frac{L_{ik}}{\tilde{L}_i}\right) - \sum_i \left(\frac{w_{il} - \bar{w}_i}{2}\right) \ln\left(\frac{L_{il}}{\tilde{L}_i}\right),$$

where L_{ij} is the number of employees in the ith category for the jth (time differentiated) carrier, L_j is the aggregate index of labor input for the jth carrier, the w_{ij} are the compensation shares, and the tildes and bars represent geometric and arithmetic means, respectively. This index number is

Table I

Sample of Air Carriers Used in the Study[a]

Air Carrier	Years Investigated
American	70–81
Braniff	70–81
Continental	70–81
Eastern	70–79, 81
North West	71, 73–77, 79–81
United	70–78, 80–81
Western	70–81
US Air	70–81
Frontier	70–81
Ozark	70–72, 74–78, 81
Piedmont	70–81
Delta	70–81
National	71–73, 76–79
Air West	70–71, 73–78, 80
North Central	70–78
Southern	70–78
Texas International	70–73, 76–81

[a] A year is missing if the air carrier sustained a strike in excess of 25 days in that year.

dollars per gallon. Materials is a residual category. Its price is computed by a Tornqvist index of seven categories which were aggregated via the multilateral procedure.[27] Capacity, the fixed input, is measured as the sum of the annual service flows (measured in constant 1977 dollars) from flight equipment and ground property and equipment.[28] Output is a multilateral index aggregating four categories of outputs: revenue passenger-miles of scheduled and charter services, and revenue ton-miles of mail and all other freight. Scheduled services account for most of the revenue, and since the revenue share of the other categories is very small, the aggregation will hardly affect the results.[29]

We include in the model firm specific operating characteristics such as average stage length (the average distance between take-offs and landings), load input (the ratio of seat-miles to seat-miles actually flown), and points served describing the air carriers network.

We have collected additional data pertaining to the firms' financial structure. As a measure of indebtedness we use the level of long term debt and the net

comparable over time within an air carrier and across air carriers and establishes transitive comparison across all observations (time-series of cross-section of firms) through binary comparisons between each of the observations and the mean of the data.

[27] Note that (following Caves et al. (1984)) within each year the price of materials is assumed constant across firms. This procedure is necessitated by the lack of firm specific quantity information.

[28] As shown by Caves, Christensen, and Tretheway (1984) this, rather than a constant dollar valuation of the capital stock, is the correct measure of capacity to produce output in any given year. Ground property and equipment comprises a negligible cost share, approximately 2% of total costs.

[29] Furthermore, Good, Nadiri, and Sickles (1987) demonstrate that the profit maximizing cross output elasticity of substitution is almost unity, indicating that the aircarriers' output can be treated as homogeneous.

present value of lease commitments.[30] Long term debt was taken from the Financial Statistics of U.S. Airlines (American Statistical Index 9142-12).[31] Data on both financial and operating lease commitments were taken from the footnotes to the Annual Reports, supplemented by the 10-K filings with the Securities and Exchange Commission.

During the period lease reporting requirements changed several times. Prior to 1973, under APB 15 leases were not capitalized on the firm's balance sheet and only the current lease obligation was reported. Between 1973 and 1976, due to APB Opinion 31, the present value of both operating and financial leases was reported. After 1976, under FASB 13, both the current and future commitments for financial and operating leases are shown, but the NPV of operating leases is not disclosed. In cases where NPV of the operating lease commitment was not disclosed it was calculated from the reported future minimum commitments, using the rate of discount used by the company to calculate the NPV of the financial leases.[32]

Data summary statistics are presented in Table II. The stochastic specification of the model, the estimation procedure used, and the empirical results are presented in the next section.

IV. Stochastic Specification, Estimation, and Results

To implement the model, we use pooled firm level data pertaining to 17 major U.S. air carriers for the period 1970–1981.[33] The variable inputs specified are labor (L), fuel (E) and materials (M). The specific operating characteristics (τ_s) specified are load input (R), stage length (S), and points served (P).

The estimation model consists of the variable cost function (2) and its associated share equations (3). We follow the literature by appending additive disturbance terms to each of these equations. It is assumed that the resulting disturbance vector is independently and identically multivariate normally distributed with mean vector zero and constant nonsingular covariance matrix.[34] Efficient param-

[30] Leases differ from conventional debt in that, in some circumstances, it is less costly to repossess leased assets in bankruptcy. As our model does not rely on bankruptcy costs, the distribution of leases and debt is of no consequence. Note that if bankruptcy occurs as a result of an industry-wide decrease in demand, the creditor will suffer a loss due to the consequent excess capacity even if there exists a secondary market for the asset.

[31] Agency costs may depend both on the total indebtedness and on the riskiness of debt. In order to account for the risk characteristics of debt, we have estimated the cost function (2) where the ln D argument was replaced by a functional whose arguments were ln D and a vector of dummy variables representing riskiness according to the firm specific bond rating obtained from Moody's. Results from that estimation indicate that the coefficients of the specified risk-dummies were statistically insignificant, perhaps as a result of insufficient dispersion in bond ratings.

[32] Marston and Harris (1988) discuss the problems in calculating the financial obligations resulting from leases.

[33] Caves, Christensen, and Tretheway (1981) document the fact that these carriers dominate the statistics of virtually any aspect of the industry; e.g., in 1975 they accounted for 86% of the revenue passenger-miles produced by the industry. Note also that new carriers are not required to file the same data as the trunks and the locals.

[34] This distributional assumption on the errors is standard and is fundamental in the derivation of the FIML estimator. A multivariate logistic distribution might be a better specification, but there is no algorithm that will generate FIML estimates under this specification.

Table II

Descriptive Statistics of Key Variables in the Sample

Variable[a]	Mean	Min	Max
Total Cost ($ billion)	1.2	0.065	5.127
Variable Cost ($ billion)	0.93	0.055	4.325
Avg. Wage ($ thousand)	61.112	31.176	108.820
Fuel Price ($/gal.)	0.35	0.10	1.06
Output (index)	0.61	0.033	2.165
Debt ($ billion)	0.611	0.056	2.445
Avg. Load (%)	0.547	0.383	0.676
Points Served	68	34	133
Avg. Stage Length (miles)	528.5	120.5	1619.7

[a] Total cost includes the cost of labor, fuel, flight equipment, ground property and equipment (GPE), and materials, a residual category. Flight equipment and GPE are measured on a replacement cost method. Variable cost does not include flight equipment and GPE. Average wage is given for pilots and copilots only. Fuel price is dollars per gallon. Output is a multilateral index aggregating four categories of inputs: revenue passenger-miles of scheduled and charter services, revenue ton-miles of mail and all other freight. The debt variable includes financial and operating leases. Average load is the ratio of seat miles sold to seat miles actually flown. Points served is the number of airports which the carrier serves on a scheduled basis. Average stage length is the average distance between takeoffs and landings.

eter estimates are obtained using full information maximum likelihood techniques applied to $n-1$ equations.[35] The resulting estimates are invariant to which share equation is deleted (Barten (1969)). It is important to emphasize that our model (see equation (1)) explicitly indicates that costs are minimized conditional on the level of capacity which has been chosen to maximize the *expected* value of equity.[36] Thus, as suggested by Zellner, Kmenta, and Dreze (1966), it is reasonable to assume that the value of the disturbance is not known until *after* the level of capacity is chosen. In this case capacity level does not depend on the disturbance, and our estimates are not subject to simultaneity bias. This rationale is to be contrasted with the traditional rationale for assuming deterministic (i.e., conditional on known disturbance) optimization which is inconsistent with the generally accepted interpretation of the disturbance. Furthermore, as Chamberlain (1984) and Mundlak and Hoch (1965) have shown, even if the management

[35] Note that in a multivariate system of equations, the effective number of observations equals the actual number multiplied by the number of equations in the system. Thus, our effective number of observations is 440 ((12 years $\times$ 17 air carriers $-$ 23 missing observations) $\times$ 3 independent equations $-$ (26 variables not appearing in the two share equations $\times$ 2)). The number of free parameters (including time and firm specific dummies) is 113. Thus we have 327 degrees of freedom.

[36] Our specification assumes that the debt level affects costs but that cost does not affect the debt level. We have tried to test for causality by regressing debt (costs) on lagged costs and debt in a pooled time-series cross-section. In line with our specification debt "causes" costs, but costs do not "cause" debt.

observes the values of the disturbances prior to choosing the level of inputs, because we include fixed firm effects (dummies), our specification yields consistent estimates of the various elasticities provided that interfirm differences are permanent or change relatively slowly over time. The parameter estimates of the translog cost function are reported in Table III.[37]

The parameter estimates are quite good based on conventional goodness-of-fit statistics. The R^2 for the cost function, fuel, and material share equations are, respectively, 0.9987, 0.9506, and 0.5806.[38] All estimated (mean) variable input shares β_L, β_E, and β_M are positive, and own price elasticities are negative, which is required by input demand theory.[39]

We have tested the hypothesis that the level of debt does not affect the firm's costs and its use of inputs, i.e., that debt is not an argument of the cost function. Using the likelihood ratio test, the critical χ^2 (with eight degrees of freedom) is 26.125 at the 0.1% significance level. The actual χ^2 is 47.14; thus, we reject the hypothesis that the level of debt does not affect the firm's costs and the choice of inputs at any level of significance. The cost of elasticity of debt is

$$\begin{aligned} \varepsilon_{cD} &\equiv \partial \ln VC/\partial \ln D \\ &= \gamma_D + A_{DD}\ln D + \textstyle\sum_j A_{jD}\ln w_j + \sum_s A_{sD}\ln \tau_s + A_{yD}\ln y + A_{kD}\ln k. \qquad (5) \end{aligned}$$

The point estimate of ε_{cD} is γ_D, which equals 0.0351 with t-statistic of 2.1135. Due to non-homotheticities,[40] as observations (firms at specific time periods) deviate from the point of approximation (the sample mean), the cost of elasticity of debt will be affected by the varying levels of debt, variable-input prices, operating characteristics, output, and level of capacity. We measured the cost elasticity of debt at each sample point. The average of the cost elasticities of debt at each sample point is 0.0338. This estimate is virtually identical to our point estimate, pointing to the tight estimation results. Thus, on average, a 10% increase in debt has resulted in a 0.34% increase in total variable cost. This finding is consistent with models of agency costs that predict a decrease in efficiency as the debt level increases.

The second-order coefficients in (5) measure the effect their respective variables have on the cost elasticity of debt as observations depart from the sample mean (our point of approximation). A positive A_{DD} coefficient indicates that the

[37] Our model implicitly adjusts the debt variable by firm size, as measured by the level of output. We can also explicitly adjust debt by the value of the firm's assets. The results obtained with this alternative specification are qualitatively similar.

[38] Recall that materials represent a residual input category and that within each year the price of materials is assumed constant across firms, which accounts for the relatively low R^2 for this share equation.

[39] The (short-run) own price elasticities of input demands for the translog cost function are calculated as follows: $E_{ii} = A_{ii}/\Phi_i + \Phi_i - 1$, where A_{ii} is the coefficient of the second order price variables and S_i is the ith cost share. Using this formula the own price elasticities (t-statistics) are: −0.0396(−2.9763), −0.1269(−3.0210), and −0.0409(−2.0827) for i = labor, materials, and fuel, respectively. Note that positive coefficients on the first-order price terms are sufficient for regularity (curvature) conditions to hold at the sample mean (our point of approximation).

[40] A production function is said to be homothetic if input proportions are constant regardless of the level of output produced and/or debt raised.

Table III

Parameter Estimates of the System of Equations Consisting of the Cost Function and its Associated Share Equations[a]

Parameter[b]	Estimate	Standard Error	Parameter[b]	Estimate	Standard Error
α_o	13.0625	.0441	A_{ML}	−.1313	.0321
α_y	.7115	.0469	A_{PD}	.0207	.0503
β_L	.4266	.0025	A_{yL}	−.0605	.0204
β_E	.1999	.0014	A_{yE}	.0415	.0114
β_M	.3734	.0024	A_{PL}	.0484	.0128
β_K	.1228	.0458	A_{PE}	−.0248	.0072
δ_s	−.1214	.0566	A_{SL}	−.0259	.0155
δ_R	−.1240	.0793	A_{SE}	.0141	.0088
δ_P	.2829	.0371	A_{RL}	.1573	.0139
γ_D	.0351	.0166	A_{RE}	−.1424	.0219
A_{LL}	.2277	.0317	A_{DL}	.0212	.0067
A_{EE}	.1518	.0038	A_{DE}	−.0188	.0037
A_{LE}	−.0965	.0063	A_{DR}	−.0414	.0991
A_{PP}	.2724	.1738	A_{DS}	−.0436	.0427
A_{yy}	−.0075	.2404	A_{DM}	−.0024	.0065
A_{SS}	−.3498	.1916	A_{LK}	.0379	.0187
A_{RR}	−.3648	.8868	A_{EK}	−.0117	.0106
A_{DD}	.0291	.0328	A_{KK}	.1428	.2085
A_{Sy}	.3251	.1605	A_{SK}	−.1462	.1295
A_{Ry}	.6025	.3065	A_{RK}	−.1219	.2973
A_{Py}	.2216	.1313	A_{yK}	−.0659	.2094
A_{PR}	−.7473	.2303	A_{PK}	−.3608	.1115
A_{PS}	.0064	.1212	A_{DK}	.0290	.0630
A_{SR}	−.9307	.2409	A_{PM}	−.0236	.0123
A_{Dy}	−.0582	.0522	A_{SM}	.0118	.0148
A_{MM}	.1866	.0336	A_{RM}	−.0148	.0385
A_{ME}	−.0553	.0063	A_{yM}	.0191	.0194
A_{MK}	−.0262	.0178	A_{DM}	−.0024	.0065

[a] Estimates of the parameters of the translog cost function (2) and share equations (3) are obtained using full information maximum likelihood.

[b] The subscripts refer to the variables as follows: y is output, L is the price of labor, E is the price of fuel, M is the price of materials, k is capacity, D is debt, P is points served, S is stage length, and R is average load. Equation (2) includes additional time as well as firm-specific dummy variables that are not reported.

cost elasticity of debt increases for firms whose debt levels exceed the sample mean value of debt and vice versa. The estimate, $A_{DD} = 0.029$, indicates that debt causes costs to increase at a higher rate as debt levels increase.

As we have shown, the firm's financial structure affects its choice of variable inputs. Thus, a firm with high leverage will produce a given level of output with a different mix of inputs than a firm with low levels of debt outstanding. This suggests that the economies of scale that a firm realizes as its output increases will depend on its debt level.[41] Using the cost function given in equation (2), it can be shown that, at the point of approximation, the elasticity of scale economies

[41] Since $A_{yd} = -0.058 < 0$ increases in debt will lead lower costs as the firm's output increases. This may be due to more effective monitoring of larger firms by investors.

with respect to debt is given by $(\partial \text{scale}/\partial D)(D/\text{scale})$ and is equal to $-\left\{A_{kD} + (A_{yD} + A_{pD})\frac{1-\beta_k}{\alpha_y + \delta_P}\right\} \Big/ (1 - \beta_k)$, where scale $\equiv [(1 - \beta_k)/(\alpha_y + \delta_P)]$. This elasticity equals 0.0047.[42] Thus, in addition to increasing costs at any given level of output (measured by $\partial \ln C/\partial D > 0$, a displacement of the average cost curve), debt also increases the measured scale economies (a movement along the average cost curve) and in this respect confers a competitive advantage on larger firms.

The effect of increasing indebtedness on total variable costs at the margin is given by $\partial VC/\partial D$. The mean estimate of $\partial VC/\partial D$ is 0.03. Thus, a permanent \$1 increase in the firm's debt increases the firm's costs by 3 cents. This is below the likely magnitude of the corporate interest tax shields: for example, a typical firm paying 12% interest and facing a 48% tax rate saves up to 5.76 cents (per dollar debt) annually on corporate taxes. The relative magnitudes of tax savings and marginal costs of indebtedness are reasonable since there exist costs of debt financing beyond those identified here and the effective tax rate may be below the statutory tax rate.[43]

The point elasticity of demand for the jth variable input with respect to debt is measured as

$$\varepsilon^P_{xjD} \equiv \partial \ln x_j/\partial \ln D = \gamma_D + A_{jD}/\beta_j, \qquad j = L, E, M. \tag{6}$$

The mean values for these elasticities are 0.0849, −0.0738, and 0.0272 for labor, fuel, and materials, respectively. Thus, debt has increased the demand for labor and materials and reduced the demand for fuel, which is consistent with its biased effects on equilibrium variable input shares discussed earlier.

Of much interest is the effect of debt on departures from optimal capacity and consequently from the minimum long-run costs. Our theoretical model indicates that capacity is chosen to maximize the value of equity. As a result, capacity may depart from the long-run optimal level that maximizes the value of the firm.[44] The first order coefficient on capacity β_k is 0.1228, indicating that at the sample mean, ceteris paribus, a 1% decrease in capacity would result in a 0.12% decrease in variable costs. This is consistent with related studies' findings which document excess capacity for the airline industry (Caves et al. (1984)).

The optimal capacity may be determined by solving the envelope condition for a given output level. Define total (long-run) cost TC to be the sum of variable

[42] Cost per unit of output may vary among firms depending on the specific nature of the network served. There is reason to believe that unit costs associated with a given level of output were lower for more compact route structures. Thus, the measure of returns to scale should reflect the variation in unit costs with respect to a proportional change in both network size (expressed here in terms of points served) and the provision of output.

[43] Other costs of debt financing include the cost of suboptimal investment in capacity, discussed below, the costs of being unable to enter into explicit or implicit contracts with customers (e.g., Titman (1984) and Maksimovic and Titman (1990)) and competitors (e.g., Maksimovic (1988)), and costs of bankruptcy. Estimates of direct and indirect costs of bankruptcy are provided by Warner (1977) and Altman (1984), respectively.

[44] Long-run optimal capacity here refers to that level consistent with production of a given level of output in the absence of any constraints.

and fixed costs, $TC = VC + p_k k$, where p_k is the price of capital. If the firm employs the optimal capacity, k^*, it must be the case that $\partial TC/\partial k^* = 0$, which implies $\partial TC/\partial k^* = \partial VC/\partial k^* + p_k = 0$. This latter equation enables us to calculate the long-run optimal level of capacity for each firm and time specific observation from our estimated variable cost function (2).

We solved for the optimal level of capacity that equates the value of the marginal product of capacity with its price for the given values of the exogenous variables in the sample. Total costs were then obtained by adding variable costs, calculated at the optimal capacity level, to the cost of optimal capacity. The estimated variable cost function implies that a movement to the optimal level of capacity would lead to total costs which were 85% as high as those observed. To assess the contribution of leverage to the departure of costs (TC) from their optimum level (TC^*), we regressed $\ln(TC^*/TC)$ on $\ln D$ and all other exogenous variables in the model.[45] The elasticity $\partial \ln(TC^*/TC)/\partial \ln D = \zeta$ can be interpreted as the elasticity of (suboptimal) costs with respect to debt for a given optimal long-run costs. The parameter estimate (t statistic) of ζ is -0.0503 (-5.60), indicating that, ceteris paribus, a 10% increase in debt increases costs (relative to the long-run optimum) by roughly 0.5%.[46] Thus, debt, in addition to its effect in increasing variable costs, may have induced inefficiencies by contributing to excess capacity and thereby bringing about a departure from long-run minimum costs. Overinvestment in capacity, which is easier to monitor than other inputs and is collateralizable, may be a response to potential conflicts of interest arising from the firm's financing decisions.

V. Debt and Total Factor Productivity

In the previous section we examined whether there exists a systematic variation between leverage and their efficiency. We have demonstrated that there exist statistically significant agency costs of debt for the air carrier industry. In this section we estimate the relative effect of agency costs of debt compared to other determinants of changes in cost efficiency of air carriers over the sample period. Cost efficiency changes over time for five reasons: (a) movement along a given average cost curve resulting from scale economy and output growth, (b) a shift in the average cost curve resulting from technological change, (c) a shift in the average cost curve due to changes in operating characteristics, (d) a shift in the average cost curve due to the effect of leverage on the use of variable inputs, and (e) a shift in average cost due to departure from long-run optimal capacity. The contribution of each of these determinants is estimated by calculating the changes in the efficiency of the firms' use of inputs, or total input productivity growth, and estimating the proportion attributable to changes in each of the determinants.

[45] The OLS $\bar{R}^2$ for this regression is 0.93.

[46] We have also tried including the current debt level as an explanatory variable in addition to lagged debt. The parameter estimate of current debt proved insignificant. Furthermore, the parameter estimate of lagged debt increased slightly in absolute value to -0.068, a finding consistent with our theoretical model.

Proceeding more formally, let $TC = VC + p_k k$, where TC represent total costs and

$$VC = g(\mathbf{w}, k, D, \tau, t) \tag{7}$$

represent variable costs, t is an index of time which is used as an indicator of the level of technology, and all other variables as previously defined.[47]

Totally differentiating (7) with respect to time yields

$$\frac{dVC}{dt} = \sum_j \frac{\partial g}{\partial w_j} w_j w_j' + \frac{\partial g}{\partial y} yy' + \frac{\partial g}{\partial D} DD' + \sum_i \frac{\partial g}{\partial \tau_i} \tau_i \tau_i' + \frac{\partial g}{\partial k} kk' + \frac{\partial g}{\partial t}, \tag{8}$$

where primes denote time derivatives. Applying Shephard's Lemma and dividing (8) through by VC yields

$$VC' = \sum_j \frac{w_j x_j}{VC} w_j' + \frac{\partial \ln VC}{\partial \ln y} y' + \frac{\partial \ln VC}{\partial \ln D} D' + \sum_i \frac{\partial \ln VC}{\partial \ln \tau_i} \tau_i' + \frac{\partial \ln VC}{\partial \ln k} k' + \frac{\partial \ln VC}{\partial t},$$

using elasticity expressions and, defining $t' \equiv \dfrac{\partial \ln VC}{\partial t}$, we get

$$VC' = \sum_j \frac{w_j x_j}{VC} w_j' + \varepsilon_{cy} y' + \varepsilon_{cD} D' + \sum_i \varepsilon_{c\tau_i} \tau_i' + \varepsilon_{ck} k' + t', \tag{9}$$

where $\varepsilon_{cy} \equiv \partial \ln VC/\partial \ln y$, $\varepsilon_{cD} \equiv \partial \ln VC/\partial \ln D$, $\varepsilon_{c\tau_i} \equiv \partial \ln VC/\partial \ln \tau_i$ and $\varepsilon_{ck} \equiv \partial \ln VC/\partial \ln k$ are the cost elasticities of output, debt, operating characteristics, and capacity, respectively.

Note that totally differentiating $VC = \sum_j w_j x_j$ and dividing through by VC yields

$$VC' = \sum_j \frac{w_j x_j}{VC} (w_j' + x_j');$$

hence,

$$\sum_j \frac{w_j x_j}{VC} w_j' = VC' - \sum_j \frac{w_j x_j}{VC} x_j'. \tag{10}$$

Substituting (10) into (9) and rearranging yields

$$\sum_j \frac{w_j x_j}{VC} x_j' = \varepsilon_{cy} y' + \varepsilon_{cD} D' + \sum_i \varepsilon_{c\tau_i} \tau_i' + \varepsilon_{ck} k' + t'. \tag{11}$$

Define the growth in total input productivity, TFP', as the difference between output and input growth rates, so that

$$TFP' = y' - \left(\frac{p_k k}{TC} k' + \sum_j \frac{w_j x_j}{TC} x_j' \right). \tag{12}$$

[47] The index of time is expressed in terms of annual time dummies in the estimation (see equation (2)).

Rewrite (12) as

$$TFP' = y' - \left[\frac{TC - VC}{TC} k' + \frac{VC}{TC} \sum_j \frac{w_j x_j}{VC} x_j'\right],$$

and using (11) gives

$$TFP' = [(1 - M\varepsilon_{cy})y'] + [-M\varepsilon_{cD}D'] + [-M \textstyle\sum_i \varepsilon_{cp_i}\tau_i'] \\ + [-(1 - M + M\varepsilon_{ck})k'] + [-Mt'], \quad (13)$$

where $M \equiv \dfrac{VC}{TC}$.

Given the information on growth of output, debt, operating characteristics, and capacity and their respective cost elasticities, we can use equation (13) to calculate total input productivity growth and decompose it into its sources.

The first term in (13) represents the scale effect. Productivity growth through the scale effect is characterized by a movement along the unit cost curve. The second term is the direct effect of debt on productivity. It is characterized by a vertical displacement of the unit cost curve. The third term measures the productivity contribution of the operating characteristics and is also characterized by a vertical displacement of the unit cost curve. The fourth term measures the productivity contribution of a departure from (long-run) optimal capacity, also characterized by a displacement of the unit cost curve. The last term measures the productivity contribution of technical change, which results in a shift of the unit cost as well.

All the variables in (13) are directly obtained from either the data (for the variables D', y', k', and τ'), or from the estimated cost function (for the parameters ε_{cD}, ε_{cy}, ε_{ck}, and $\varepsilon_{c\tau_s}$). The time variable t' needs, however, to be calculated since we use time shifts (dummy variables) rather than a time trend in the cost system regression. Thus t' is calculated as $(\rho_T - \rho_{T-i})/(T - i)$, where the ρ's are the time shift coefficients and T and i are specific time periods. Estimates of TFP growth and its sources are presented in Table IV.

Our estimation of TFP' indicates that it has grown at an annual average of 3.96%. In examining individual subperiods it is important to note that the growth of TFP through time is sensitive to the overall growth rates of the economy and the industry. As a result, during the recession period, 1980–1982, productivity growth became negative. This decline is largely attributed to a decrease in the utilization of capital and is reflected by the relatively high negative contribution of the deviation of capacity from the optimum (last column of Table IV).[48]

Of more importance to us is the fact that changes in leverage that occurred over the sample period have reduced the growth of TFP by an annual average of 0.001 or 2.6% of the total. This decrease was caused by the input misallocation, and the resulting inefficiencies, analyzed in the previous sections. It is also important to remember that debt, aside from increasing cost at any level of output, has also substantially contributed to the divergence of capacity from its optimum. Our results indicate that non-optimal capacity has reduced the growth

[48] This effect has also been noted by Bailey, Graham, and Kaplan (1985).

Table IV

Sources of Productivity Growth: Average Annual Rates of Growth[a] (Means over All Firms)

Period	Productivity Growth TFP'	Debt[b] $M\varepsilon_{cD}dD'$	Scale $(1 - M\varepsilon_{cy})y'$	Network $M \sum_\iota \varepsilon_{c\tau_\iota} \tau_i'$	Technical change Mt'	Non-Optimal capacity[c] $(1 - M + M\varepsilon_{ck})k'$
1971–74	0.0457	0.0006	0.0403	0.0036	0.0137	−0.0125
1975–78	0.0587	−0.0014	0.0411	0.0027	0.0262	−0.0098
1979–81	−0.0023	0.0027	0.0185	0.0105	−0.0054	−0.0232
1971–1981	0.0396	−0.0010	0.0353	0.0049	0.0144	−0.0140

[a] Estimates of the contributions of scale economies, network economies, technical change, non-optimal capacity, and the direct effect of debt on variable inputs are either obtained from (13) using the estimated cost function (for the parameters ε_{cD}, ε_{cy}, ε_{ck}, $\varepsilon_{c\tau_s}$, and t') or are directly obtained from the data (for the variables D', y', k', and τ').

[b] The estimates in this column measure only the direct effect of changes in debt levels on the utilization of variable inputs.

[c] Estimates in this column include an indirect effect of debt through its effect on the capacity decision.

of *TFP* to an extent that cancels out the gain from technical advance. The net positive rate of productivity growth is thus principally due to increasing returns to scale and output growth. As indicated above, for the class of agency problems that we analyze costs increase less than proportionally with the scale of operations.[49] Thus, a portion of the realized benefit of large scale operations may be due to a reduction of agency costs from input misallocation.

VI. Conclusion

In this paper we have applied econometric techniques developed for the estimation of cost functions in order to estimate the effect of the firm's financial structure on its production decisions. Our analysis has demonstrated that costs of debt financing that result from input misallocation can be directly estimated and depend on observable characteristics of the firm's technology. The methodology for estimating costs was applied to a major industry, passenger air transport. The findings are consistent with the hypothesis that financial structure affects input decisions in this industry. High debt levels are associated with suboptimal investment in capacity and inefficient combinations of variable production inputs. At the margin, the loss of efficiency from an increase in indebtedness is large enough to dissipate a substantial fraction of the potential tax benefits of debt financing. There is also evidence that industry wide changes in leverage have had a negative effect on the growth of productivity in the sample period.

Our results are consistent with agency models that predict a decrease in efficiency as the debt level increases. Significantly, we do not find support for agency models that suggest a positive association between the debt level and

[49] This is consistent with the hypothesis that external monitoring is more effective in the case of large firms.

efficiency.[50] A part of the loss of efficiency that we identify is attributable to the greater use by levered firms of inputs that can be monitored and are collateralizable. Increased reliance on such inputs may be a response to potential conflicts of interest arising from the firm's financing decisions.

While they pertain to a single industry and a specific period, these results are encouraging and indicate that further attempts to test the effect of financing decisions on the firm's use of inputs are warranted. It would be interesting to explore the robustness of our findings by applying the same methodology to other industries and by adopting alternative specifications. It would also be valuable, although difficult, to recast and reestimate the agency problem in a dynamic framework to take into account the costs of adjusting input as financial structure changes.

[50] Our findings do not preclude the possibility that leverage reduces some other kinds of agency costs.

REFERENCES

Altman, E. I., 1984, A further investigation of the bankruptcy cost question, *Journal of Finance* 39, 1067–1089.

Auerbach, A., 1985, Real determinants of corporate leverage, in B. Friedman, ed.: *Corporate Capital Structures in the United States* (University of Chicago Press, Chicago, IL).

Bailey, E. E., D. R. Graham, and D. P. Kaplan, 1985, *Deregulating the Airlines* (MIT Press, Boston, MA).

Barnea, A., R. A. Haugen, and L. W. Senbet, 1985, *Agency Problems and Financial Contracting* (Prentice Hall, Englewood Cliffs, NJ).

Barten, A. P., 1969, Maximum likelihood estimation of a complete system of demand equations, *European Economic Review* 1, 7–73.

Berndt, E. R. and M. A. Fuss, 1986, Productivity measurement with adjustments for variations in capacity utilization, and other forms of temporary equilibrium, *Journal of Econometrics* 33, 7–29.

Bhattacharyya, S. and V. Maksimovic, 1990, Agency costs and the monitoring of inputs, Mimeo, University of British Columbia.

Bradley, M., G. Jarrell, and E. Kim, 1984, On the existence of optimal capital structures: Theory and evidence, *Journal of Finance* 39, 857–878.

Brander, J. A. and T. R. Lewis, 1986, Oligopoly and financial structure, *American Economic Review* 76, 956–971.

——— and B. J. Spencer, 1989, Moral hazard and limited liability: Implications for the theory of the firm, *International Economic Review* 30, 833–851.

Caves, D. W., L. R. Christensen, and W. E. Diewert, 1982, The economic theory of index numbers and the measurement of input, output, and productivity, *Econometrica* 50, 1393–1414.

———, L. R. Christensen, and M. W. Tretheway, 1984, Economics of density vs. economics of scale: Why trunk and local service airlines' costs differ, *Rand Journal of Economics* 15, 471–489.

———, L. R. Christensen, and M. W. Tretheway, 1981, U.S. trunk air carriers 1972–1977: A multilateral comparison of total input productivity, in T. Cowing and R. Stevenson, eds.: *Productivity Measurement in Regulated Industries* (Academic Press, New York, NY).

Chamberlain, G., 1984, Panel data, in Z. Griliches and M. Intriligator, eds.: *Handbook of Econometrics*, Vol. 2 (North Holland, Amsterdam, Holland).

Christensen, L., D. Jorgenson, and L. Lau, 1973, Transcendental logarithmic production functions, *Review of Economics and Statistics* 55, 28–45.

Diewert, W. E., 1971, An application of the Shephard duality theorem: A generalized Leontief production function, *Journal of Political Economy* 79, 481–507.

Fama, E. F., 1980, Agency problems and the theory of the firm, *Journal of Political Economy* 88, 288–307.

Fischer, E. O., R. Heinkel, and J. Zechner, 1989, Dynamic capital structure and choice: Theory and tests, *Journal of Finance* 44, 19–41.

Good, D. H., M. I. Nadiri, and R. C. Sickles, 1987, The structure of production and technical change in a multiproduct industry: An application to the airline industry, Unpublished manuscript, Rice University.

Grossman, S. J. and O. D. Hart, 1982, Corporate financial structure and management incentives, in J. J. McCall, ed.: *Economics of Information and Uncertainty* (University of Chicago Press, Chicago, IL).

Haugen, R. and L. Senbet, 1988, Bankruptcy and agency costs: Their significance to the theory of capital structure, *Journal of Financial and Quantitative Analysis* 23, 27–38.

——— and L. Senbet, 1981, Resolving the agency problems of external capital through options, *Journal of Finance* 36, 629–647.

Heinkel, R. and J. Zechner, 1990, The role of debt and preferred stock as a solution to adverse investment incentives, *Journal of Financial and Quantitative Analysis* 25, 1–25.

Jensen, M., 1986, Agency costs of free cash flow, corporate finance and takeovers, *American Economic Review* 76, 323–330.

——— and W. Meckling, 1976, Theory of the firm: Managerial behavior, agency costs, and ownership structure, *Journal of Financial Economics* 3, 305–360.

John, K. and D. C. Nachman, 1985, Risky debt, investment incentives, and reputation in a sequential equilibrium, *Journal of Finance* 40, 863–878.

Kim, M. and V. Maksimovic, 1990, Technology, debt, and the exploitation of growth options, *Journal of Banking and Finance*, Forthcoming.

Long, M. S. and E. B. Malitz, 1985, Investment patterns and financial leverage, in B. Friedman, ed.: *Corporate Capital Structures in the United States* (University of Chicago Press, Chicago, IL).

Maksimovic, V., 1986, Optimal capital structure in a stochastic oligopoly, Unpublished doctoral dissertation, Harvard University.

———, 1988, Capital structure in a repeated oligopoly, *Rand Journal of Economics* 3, 389–407.

——— and S. Titman, 1990, Financial structure and reputation for product quality, *Review of Financial Studies*, Forthcoming.

Marston, F. and R. S. Harris, 1988, Substitutability of leases and debt in corporate capital structures, *Journal of Accounting, Auditing and Finance* 3, 147–163.

Mundlak, Y., 1978, On the pooling of time series and cross section data, *Econometrica* 46, 69–85.

——— and I. Hoch, 1965, Consequence of alternative specifications in estimation of Cobb-Douglas production functions, *Econometrica* 33, 814–828.

Myers, S. C., 1977, Determinants of corporate borrowing, *Journal of Financial Economics* 5, 147–176.

Ross, S. A., 1987, Finance, in J. Eatwell, M. Milgate, and P. Newman, eds.: *The New Palgrave Enclopedia of Economics*, Vol. 2 (MacMillan Press, London, United Kingdom).

Shephard, R. W., 1970, *Theory of Cost and Production Functions* (Princeton University Press, Princeton, NJ).

Spence, A. M., 1985, Capital structure and the corporation's product market environment, in B. Friedman, ed.: *Corporate Capital Structures in the United States* (University of Chicago Press, Chicago, IL).

Titman, S., 1984, The effect of capital structure on a firm's liquidation decision, *Journal of Financial Economics* 13, 137–151.

——— and R. Wessels, 1988, The determinants of capital structure choice, *Journal of Finance* 43, 1–21.

Varian, H. R., 1984, *Microeconomic Analysis* (W. W. Norton and Company, New York, NY).

Warner, J., 1977, Bankruptcy costs: Some evidence, *Journal of Finance* 32, 337–347.

Williams, J., 1987, Perquisites, risk, and capital structure, *Journal of Finance* 42, 29–49.

Zellner, A., J. Kmenta, and J. Dreze, 1966, Specification and estimation of Cobb-Douglas production functions models, *Econometrica* 34, 784–795.