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STATIC AND DYNAMIC PRODUCTIVITY DIFFERENCES ACROSS PRIVATE AND PUBLIC ENTERPRISES: THE CASE OF AIRLINES

by

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Introduction

The effect of state ownership of productive resources on efficiency has been an important topic of investigation in studies of the role of government in economic activity in general. By and large, the literature on this issue anticipates differences in efficiency in favor of private enterprises in view of considerations such as incomplete property rights and greater agency problems in the state enterprises. Somewhat surprisingly, the empirical literature does not provide an abundance of clearcut evidence in support of a systematic difference along ownership lines. Indeed, several careful studies (e.g., Caves and Christensen (1980), researching railroad companies in Canada) have not found significant differences in productivity attributable to ownership type, while other studies which find indications of greater efficiency in privately-owned enterprises (e.g., Davies (1971), (1977), investigating airlines in Australia) use only a comparison of partial factor productivities across pairs of firms, or improperly specified cost functions (see Borcherding, et al. (1982) for a survey). One important explanation for the lack of a consistent pattern, especially in cases of a pairwise comparison of private and state-owned firms, is that those firms that survive a competitive "market test" will tend to exhibit similar productive efficiency.

An independent issue of relevance, which the existing literature has by and large ignored, is the analytical and empirical separation of <u>static</u> from <u>dynamic</u> differences in efficiency across different types of enterprises. This distinction is the major focus of this paper. While differences in unit cost levels are important indicators of relative efficiency, they may be due solely to differences in the objective functions state-owned firms are mandated to pursue by the state authorities. It is thus important to explore whether differences in efficiency may be due to systematic differences in both the levels

and the rates of growth of productivity or technical efficiency across firms.

It is possible that by examining static and dynamic productivity differences together, the evidence concerning each one separately will become clearer. Furthermore, evidence of systematic differences in rates of productivity growth may have far-reaching behavioral and policy implications. For example, in the 1980s a world-wide trend toward privatization was manifested in air transport. Government ownership as a percentage of equity has fallen from 100 to 0 for Air Canada, from 100 to 0 for British Airways, from 75 to 55 for KLM, and from 99 to 27 for Sabena. All of these companies had had higher percentages of equity owned by the government during most of the post-war period. Such a trend toward privatization may be the result of the increasing market pressures that slower productivity growth places on state-owned firms.

To the extent that enterprises of different ownership face the same production possibilities and have access to the same factor markets, systematic differences in their productivity growth rates must be interpreted through a model that allows for growth in some firm-specific technology. Such a model is developed in section I of the paper, which follows closely Ehrlich and Lutter (1989). In this model, "organization capital" serves as an engine of productivity growth, and its accumulation over time is the consequence of an optimal allocation of entrepreneurial resources between enhancing current production and building additional firm-specific knowledge and skills. Our approach toward endogenous, firm-specific productivity growth complements recent models of economy-wide endogenous productivity growth that identify human capital or disembodied technological innovations as engines of persistent growth in per-capita income. Conceivably, some of the steady-state rates of economy-wide productivity growth occur as a result of growth in factors <u>internal</u> to the firm as opposed to growth in general human capital or technology that takes place outside of the representative firm.

In section II we pursue some of the basic implications of this model empirically, using data from an international sample of 23 generally comparable airlines of different ownership categories over the period 1973-1983. We calculate total factor productivity indices using the methodology developed by Christensen and Jorgenson (1970), and estimate cost functions using techniques developed by Christensen and Greene (1976). We then examine evidence concerning estimates that are related to the effects of government ownership of airlines: (a) differences in firm specific productivity growth, (b) static inefficiencies, and (c) differences in labor demand.

Our theoretical analysis leads to several propositions, some of which we have been able to test empirically.

(a) Both the level and rate of growth of firm-specific productivity may differ by ownership type due to the effect of the latter on the rate of growth of organization capital, and hence productivity.

(b) A deviation from profit-maximizing objectives (e.g., a preference for labor employment) in the state-owned firms should affect factor proportions and cost levels but not the rates of firm-specific productivity growth.

(c) The growth of total factor productivity specific to the firm is independent of initial firm size. This independence is a generalization of Gibrat's law that the rate of growth of output is independent of the size of the firm.

(d) A linear relationship exists between the rate of growth of firm-specific total factor productivity and the rate of growth of firm output.

(e) Monopolistic firms that operate in a more competitive environment, i.e., face relatively high demand elasticities, will experience a higher rate of productivity growth relative to firms that operate in a more insulated environment.

(f) Firms that face lower borrowing costs or higher returns to scale will experience a higher rate of growth of firm-specific productivity.

The main result of our empirical investigation is that state-owned airlines lag behind their private counterparts in both the level and rate of growth of productivity due to differences in technical efficiency. From the statistical analyses of costs and productivities of the 23 international airlines over the 11 years of data in our sample we estimate that 100% government ownership may entail cost increases relative to private ownership in excess of 100%, and may imply rates of productivity growth that are 1.6 percentage points lower than those of a privately owned airline. We find weaker evidence for the existence of a greater demand for labor in the state-owned airlines after accounting for prices and outputs.

I. A Model of Self-Generating Productivity Growth at the Firm Level

The model we develop in this section is designed to provide an analytical framework for organizing and interpreting evidence of apparent diversity in both levels and rates of growth of firm-specific productivity across publicly and privately owned enterprises. To accomplish this task, we need to ascribe observed variations of productivity, at least in part, to factors that are internal to the firm, rather than those that reflect its external environment, i.e., industry or economy-wide trends in productivity. Also, inasmuch as the evidence indicates systematic differences in the rate of growth of productivity across different types of firms, we deem it desirable to ascribe these differences to factors which account for steady-state rates of firm-specific productivity growth, rather than to transitional deviations from long-run productivity levels (transitional dynamics). We thus attempt to develop a model of endogenous, self-generating growth at the firm level.

We identify the potential source of firm-specific productivity growth as "organization capital", by which we mean, essentially, the level of entrepreneurial knowledge and effectiveness at which the firm is managed. We

conceive of organization capital as specialized information and organization skill which improves the interactions among individual managers, employees, vendors and even customers, and augments the production capacity of all inputs in their specialized tasks. Such improvements can be achieved through efficient matching of organization members and specific tasks (cf. Prescott and Visscher (1980)), efficient learning and implementation of exogenous disembodied innovations, and "specific" training of workers or adaptation of capital inputs to their specific tasks within the firm.

Our point of departure in the following analysis is that organization capital itself is subject to dynamic accumulation in the same way that human capital (embodied general knowledge) appears to accumulate over time. Indeed, some of the growth "mechanics" we adopt below are similar to those used in recent papers on endogenous growth (e.g., Lucas (1988), and Becker and Murphy (1989)) which ascribe self-generating economy-wide growth in per-capita income to the accumulation of human capital. Organization capital thus serves as the "engine of growth" of firm-specific productivity in this model.

A. Basic Assumptions

We identify "entrepreneurial capacity", i.e, entrepreneurial time and effort, as an essential scarce resource which is both "firm specific" and nonduplicable: Entrepreneurs or top executives who share the firm's residual income invest in knowledge of the specific circumstances in which their firms operate. And while other managers (subsumed under the "labor" input below) can serve as an extension of the entrepreneur, they are imperfect substitutes for the role of the person(s) at the top of the firm's hierarchy system.

Entrepreneurial inputs, in turn, perform two basic functions: a) monitoring and directing current production efforts in a way that augments all factors' productivities; b) building additional entrepreneurial capacity or

organization capital. The first of these functions can be captured by the following specification of the production function, simplified to assume a Cobb-Douglas form:

(1) $Q(t) = F(K(t), L(t), H(t)M(t)) = K(t)^{\alpha}L(t)^{\beta}[H(t)M(t)]^{\gamma}$,

where H denotes the amount of organization capital, M represents the fraction of entrepreneurial time devoted to directing current production efforts, and L and K stand for the services of labor and capital inputs. The second entrepreneurial function is represented by the production function of new knowledge

(2) $\overset{\circ}{H}(t) = rH(t)(1-M(t))$,

where r denotes a (general) productivity parameter, and (1-M) represents the fraction of managerial time devoted to improving organization capital. By equation (2), production of new entrepreneurial knowledge or skill is an increasing function of the stock of accumulated knowledge as well as the share of time devoted by entrepreneurs to this activity. Specifying the flow of new knowledge as a linear function of the stock of existing knowledge is critical for guaranteeing the existence of steady-state, firm-specific productivity growth.

Finally, we assume that the firm's objective function involves the traditional maximization of the present value of future profits over an infinite horizon. In the case of publicly owned firms, however, we allow for alternative decision rules that may be dictated by political factors rather than by an efficient capital market in which privately-owned firms are presumed to operate. We shall also consider the model under both competitive and monopolistic market structures.

B. The Competitive Case

To focus on the contribution to productivity of organization capital, we

define labor services in efficiency units and assume they are purchased in a perfect rental market at a constant wage rate, w. Put differently, exogenous improvements in the quality of workers due to schooling and "general" training are accounted for by the magnitude of L(t), so that w represents the rental price of "generally" trained workers. The firm's capital stock K(t), likewise defined in efficiency units, accumulates through investment flows, I(t), according to the following law of motion

(3) $\overset{o}{K}(t) = I(t) - \delta K(t)$,

where δ denotes a constant rate of depreciation of accumulated capital. The cost of investment, however, reflects both the market price of capital inputs, and adjustment costs as follows.[1]

(4) $C(I(t)) = cI(t)^{a}K(t)^{-b}$, $a > 1$, $b > 0$.

By equation (4), the marginal cost of investment is an increasing function of the (one-) unit cost of machines, c, and the scale of investment <u>relative</u> to the level of accumulated capital, i.e., $MC(I(t)) = acI(t)^{a-1}K(t)^{-b}$. In the special case where $(a-1) = b$, the marginal adjustment cost remains constant as long as I(t) and K(t) increase by the same proportion, as would be the case in a steady state.

The current value Hamiltonian function is thus given by

(5) $v(t) = K(t)^{\alpha}L(t)^{\beta}[H(t)M(t)]^{\gamma} - wL(t) - cI(t)^{a}K(t)^{-b}$

$+ \mu(t)[I(t)-\delta K(t)] + \lambda(t)rH(t)[1-M(t)]$,

using the price of output as a numeraire. The first-order optimality conditions (excluding the time reference, t,) are given by

(6) $\beta Q/L = w$

(7) $acI^{a-1}K^{-b} = \mu$

(8) $\gamma Q/M = \lambda rH$

(9) $\overset{o}{\mu} = \mu(\rho+\delta) - \alpha(Q/K) - bcI^{a}K^{-b-1}$,

(10) $\overset{o}{\lambda} = \lambda\rho - \gamma(Q/H) - \lambda r(1-M)$,

where ρ in equations (9) and (10) denotes the firm's objective discount rate, and $\overset{o}{\mu}$ and $\overset{o}{\lambda}$ denote the time derivatives of the shadow prices of physical and organization capital, respectively. The transversality condition is given by

(11) $\lim_{t\to\infty} e^{-\rho t}\,\mu(t)K(t) = 0$.

In a steady state, the optimal entrepreneurial input allocated to direct current production, M, is constant, and both the rental prices of labor and capital and their quantities grow at constant rates. Denoting the logarithmic time rate of change of a variable, X, by $\hat{X}$, and assuming that w(t) and c(t) are constant over time, equations (6) through (9) can be expressed as follows:

(6') $\hat{Q} - \hat{L} - \hat{w} = 0$

(7') $(a-1)\hat{I} - b\hat{K} = \hat{\mu}$, (note that $\hat{I} = \hat{K}$ by equation (3))

(8') $\hat{Q} = \hat{\lambda} + \hat{H}$

(9') $\hat{Q} = \hat{\mu} + \hat{K}$ (using equations (7) and (9))

(10') $\hat{\lambda} = \rho - r$ (using equations (8) and (10)),

and from equation (1) the logarithmic time rate of change of output is given by

(1') $\hat{Q} = \alpha\hat{K} + \beta\hat{L} + \gamma\hat{H}$.

The preceding set of conditions represents six independent equations in six unknowns (given that $\hat{I} = \hat{K}$). The solutions for the rates of growth of labor, capital, the shadow price of capital, output, and organization capital are given by

(12) $\hat{L} = (a-b)\hat{K} = \hat{Q}$

(13) $\hat{\mu} = (a-1-b)\hat{K}$

(14) $\hat{Q} = \gamma(r-\rho)/\{1-[\alpha/[\alpha/(a-b)]-\beta-\gamma\}$

(15) $\hat{H} = (r-\rho)\{1-[\alpha/(a-b)]-\beta\}/\{1-[\alpha/(a-b)]-\beta-\gamma\}$.[2]

This analysis shows that a dynamic growth equilibrium involving positive, self-generating growth in organization capital, and hence in output, productivity, and factor employment, exists if both $(r-\rho) > 0$ and

$\{1-[\alpha/(a-b)]-\beta-\gamma\} > 0$. The first of these conditions requires that the internal rate of return to organization capital, r, exceed the firms's discount rate, ρ. The second assures that the firm's long-run marginal cost curve (LRMC) be upward sloping so that an interior solution for all the control variables may exist in a steady-state competitive equilibrium. If a-b = 1 in equation (4), the condition $\alpha + \beta/(a-b) + \gamma < 1$ would be satisfied if, and only if, the production function (1) exhibits decreasing returns to scale. No such condition is required, however, if the marginal adjustment costs of investment in physical capital were an increasing function of the ratio of investment to existing capital (I/K), i.e., if a-b > 1, since in that case the firm's LRMC will be upward sloping even if there were constant returns to scale. The magnitude of the latter will be falling through time at any positive level of output due to the growth in organization capital.

Growth in organization capital is proportionally related to the growth in total factor productivity (TFP). The latter can be measured in the context of this formulation by the ratio of output to all paid inputs weighted (exponentially) by the elasticities of output with respect to these inputs, since by equation (1') $\gamma\hat{H} = \hat{Q} - \alpha\hat{K} - \beta\hat{L}$. Equation (15) thus identifies the following determinants of firm-specific total factor productivity growth:

<u>Proposition 1</u>: The steady-state, firm-specific growth in total factor productivity is an increasing function of entrepreneurial efficiency at producing organizational capital, r, the elasticities of output with respect to each input, α, β, γ, and the elasticity of the adjustment cost of investment with respect to physical capital, b. It is a decreasing function of the real rate of interest, ρ, and the elasticity of the adjustment cost of investment with respect to the scale of investment, a.

Proposition 1 is easily proved through direct differentiation of equation (15) with respect to the relevant parameters, and the economic intuition behind

it is straightforward: generally the incentive to invest in factor-augmenting capital will be enhanced by the productivity of roundabout methods of production relative to the shadow price of investment and by the elasticities of output with respect to all inputs, (i.e., the level of returns to scale) since the latter increase the marginal return from "factor augmentation".

Proposition 2: The steady-state rate of growth in firm-specific total factor productivity is independent of all initial conditions, including the initial size of firm output. Likewise, the rate of growth of output in the steady-state growth equilibrium is independent of the initial size of output. The rates of growth in output and in firm-specific total factor productivity, in turn, are linearly (proportionally) related.

The proof of this proposition follows directly from equations (14) and (15). The proposition is a generalization of Gibrat's law in the context of a dynamic, firm-specific growth equilibrium, and is consistent with Lucas' (1978) generalization of that law under static conditions. While we here obtain the independence between the steady-state rate of growth of output and initial firm size (Gibrat's law) in a partial equilibrium setting, we extend the applicability of the law to the independence between initial firm size and the firm-specific rates of growth of TFP as well. This distinguishes our model of endogenous firm-specific growth from models of induced process-innovation at the firm level (e.g., Dasgupta and Stiglitz, 1980) that predict a positive association between initial firm size and induced innovative activity. The reason for the expected independence between firm size and firm-specific growth in our model is that the opportunity cost of creating new organization capital is the loss in current production due to the reallocation of entrepreneurial inputs away from directing current production toward investment in organization capital. Since both the opportunity costs and the future returns from investment in organization capital are proportional to the scale of output, the rate of growth of firm-specific

knowledge, and hence TFP, should be independent of scale. Furthermore, this proposition indicates that induced firm-specific technological innovations can take place within a stable market structure: While from equations (14) and (15) we expect a proportional relationship between the rates of growth of output and productivity, as $\hat{Q} = \gamma\hat{H}/\{1-[\alpha/(a-b)]-\beta\}$, firms that are initially larger in size do not necessarily capture a growing market share as a result of firm-specific innovations. A steady-state equilibrium of firm-specific growth is compatible with a stable size distribution of firms.

Proposition 3: The steady-state growth equilibrium is characterized by constant profit margins and rates of return on capital and by finite firm values.

Proof: Define the steady-state rate of growth of output $\hat{Q} = g$. Using equations (12) and (13) the time paths of output, labor and capital employment, and the shadow price of capital are given by $Q(t) = Q_o e^{gt}$; $L(t) = L_o e^{gt}$; $I(t) = I_o e^{[1/(a-b)]gt}$; $K(t) = K_o e^{[1/a-b)]gt}$; and $\mu(t) = \mu_o \exp[(a-1-b)/(a-b)]$, where the subscript o (as in Q_o) denotes the optimal value of a control variable at the reference period. The firm's maximized profits in period t can thus be shown equal to

(15*) $\pi(t) = [Q_o - wL_o - cI_o^a K_o^{-b}]e^{gt} = \pi_o e^{gt}$,

where π_o represents maximized profits at the reference period. It follows that the rate of growth of profits equals that of output, $\hat{\pi} = g = \hat{Q}$, and that profit margins are constant over time. By similar reasoning, the rate of return on physical capital evaluated at its shadow price, $i^*(t) = \pi(t)/[\mu(t)K(t)]$ can be shown equal to $\pi_o/\mu_o K_o$, which is constant over time as well.

While total profits are rising in a perpetual growth equilibrium, the value of the firm is finite. To prove this result note that the value of the firm at the reference period is given by

$V(0) = \int_0^\infty e^{-\rho t}\pi(t)dt = \int_0^\infty \pi_o e^{(g-\rho)t}dt$ by equation (15*). By integrating the last term, the value of the firm is found equal to

(16) $V(0) = \pi_o/(\rho-g)$

The transversality condition (11) guarantees that $(\rho-g) > 0$.[3] Therefore equation (16) is positive and finite.

Note that while the rate of growth of output and productivity are independent of initial conditions by proposition (2), the levels of the firm's TFP, value, and profit margins are not, since the initial period's profit, π_0, is a function of the initial organization capital available to the firm, H(0). These differences in initial conditions can be captured by entrepreneurs in the form of pure rents, however, and they do not jeopardize the industry's competitive structure. Systematic differences in the technological parameters of the model (including entrepreneurial efficiency at producing organization capital), in contrast, are expected to cause unequal rates of growth among the corresponding firms. Consequently, they may upset the stability of the competitive equilibrium over time. In a steady-state equilibrium commensurate with competition, such differences may be smoothed out through mergers and acquisitions that ultimately result in equal firm-specific growth rates over time.

Proposition 4: Exogenous upward trends in factor prices relative to output prices that are unrelated to changes in the quality of factors reduce the firm-specific rate of endogenous growth in both output and total factor productivity.

Proof: Let the rental price of labor increase in a steady state by the rate $\hat{w} > 0$ and let the (one-)unit adjustment cost of investment in physical capital increase by the rate $\hat{c} > 0$. These changes modify the steady-state solutions for the control and state variables as follows:

(12a) $\hat{L} = \hat{Q} = \hat{c} + (a-b)\hat{K}$

(14a) $\hat{Q} = \{\gamma\hat{H} - [\alpha\hat{c}/(a-b)]-\beta\hat{w}\}/\{1-[\alpha/(a-b)]-\beta\}$

(15a) $\hat{H} = \{(r-\rho)[1-(\alpha/(a-b))-\beta]-[\alpha\hat{c}/(a-b)]-\beta\hat{w}\}/\{1-[\alpha/(a-b)]-\beta-\gamma\}$.

Clearly, then, exogenous upward trends in factor prices or downward trends in

output prices (due, say, to continuous reductions in marginal costs as a result of growth in all firms' TFP) will decrease the rate of firm-specific productivity growth because the persistent rise in the cost of factors decreases the demand for factors and thus the cost savings from building organization capital. Note that in this case the rates of growth in output and in total factor productivity are linearly, but no longer strictly proportionally, related, as can be seen directly from equation (14a).

C. The Model Under Monopoly

Since the analysis of self-generating productivity growth is applied in section II against airline industry data, it may be desirable to investigate the implications of a market structure in which government regulation and ownership may enable the firm to exercise a degree of monopoly power. More specifically, since international airline companies may obtain exclusive licenses to operate over city or country pairs and to use specific airports, their markets may not be strictly contestable in practice. However, the market for international air transportation still allows for considerable competition among airlines if, e.g., bilateral agreements among governments allow foreign airlines to operate in the same or adjacent air routes in which a "national" airline has the right to operate. The relevant market structure may thus be monopolisticly competitive.

To facilitate an explicit solution involving positive, self-generating productivity growth, we assume that the firm's demand curve exhibits constant price elasticity over the relevant range of output changes, i.e.,

(17) $p = AQ^{-\epsilon}, \ \epsilon > 0$

where A denotes the level of demand and $1/\epsilon$ the absolute value of its price elasticity. The revenue function is thus given by $R = AQ^{\eta}$, where $\eta = 1-\epsilon$. The Hamiltonian function becomes

(5.b) $v = AQ^{\eta} - wL - cI^{a}K^{-b} + \mu[I-\delta K] + \lambda rH(1-M)$,

subject to the initial and transversality conditions discussed in section B. The steady-state solutions expressed in equations (12) through (15) are modified by virtue of the fact that the rate of growth in revenue must be lower than the rate of growth of output as long as the firm's demand curve remains constant in a steady-state equilibrium so that output prices are falling.[4] In particular, equations (12), (14) and (15) become

(12.b) $\hat{L} = (a-b)\hat{K} = \eta\hat{Q}$, where $0 < \eta < 1$.

(14.b) $\hat{Q} = (\gamma\hat{H}/\eta)/[(1/\eta)-(\alpha/(a-b))-\beta]\}$, and

(15.b) $\hat{H} = (r-\rho)\{[(1/\eta)-[\alpha/(a-b)]-\beta\}/\{(1/\eta)-[\alpha/(a-b)]-\beta-\gamma\} > 0$,

if $(r-\rho) > 0$ and $\{(1/\eta)-[\alpha/(a-b)]-\beta-\gamma\} > 0$.

This analysis shows that under monopoly, growth in firm-specific total factor productivity can be positive even if there were increasing returns to scale in production ($\alpha+\beta+\gamma > 1$) and marginal investment costs were only a function of the intensity of investment (I/K) (i.e., a-b=1), provided the price elasticity of demand $[1/(1-\eta)]$ were sufficiently high. Also, by equation (12.b) the steady-state rate of growth in demand for labor and capital services is now <u>slower</u> than that of output (assuming (a-b)=1). Consequently, both total and <u>partial</u> factor productivity measures (Q/L and Q/K) will be continuously increasing in a steady state of firm-specific productivity growth.

Propositions 1 and 2 of the previous section hold in the present case as well. A major new implication, however, is

<u>Proposition 5</u>: Under a monopolistic market structure, the rate of increase of total factor productivity will be higher the higher the price elasticity of demand for the firm's product.

The proof follows directly from equation (15.b) since $d\hat{H}/d(1/\eta) = -[(r-\rho)\gamma]/J < 0$ where $J = \{(1/\eta)-[\alpha/(a-b)]-\beta-\gamma\}$. Hence, the higher the value of $0 < \eta < 1$ (the greater the price elasticity of demand), the higher will be the rate of growth

of organization capital and TFP. The incentive to accumulate organization capital increases as a function of the elasticity of demand for the firm product essentially because the latter assures relatively small declines in product prices while output expands as a result of TFP growth. The proposition implies that monopolistic firms that operate under a more competitive environment, and thus face more elastic demands for their products, will enjoy a relatively higher rate of TFP growth than firms that are more strongly insulated from competition.

The thrust of propositions (3) and (4) also remains valid in this case. In particular, we expect growth in firm output and firm-specific TFP to be invariant to the initial size of the firm, the rates of increase in output and TFP to be linearly related, and the rate of return on capital to remain constant over time.[5] To the extent that firms are subject to monopolistic competition and have identical production opportunities and some fixed production costs (hence U-shaped average cost curves) the steady-state equilibrium will be characterized by zero profits resulting from firm-specific demand shifts due to entry of close substitutes. As in the purely competitive case, however, differences in initial conditions will allow firms to capture entrepreneurial rents.

D. Ownership Effects on Firm-Specific Productivity

There are, in principle, two potential dimensions of firm productivity or efficiency that can be affected by the firm's type of ownership: technical efficiency, and allocative efficiency. The first would be manifested through differences in levels or rates of growth of total factor productivity or in the "dual" cost functions in firms that face identical production functions but are of different ownership types. Our preceding analysis ascribes such differences to different rates of accumulation of organization capital. The second would be inferred only from a comparison of firm cost and factor demand functions by

type of ownership. Given identical technologies of production, differences in the latter may be ascribed, in principle, to the association between a firm's type of ownership and its objective function. In the following analysis we explore how different types of ownership may affect each of these dimensions of overall efficiency.

D.1. Ownership and Technical Efficiency

Given our analysis in sections B and C, systematic differences in technical efficiency across firms may be due to differences in initial organization capital (entrepreneurial abilities), specific technological parameters (such as efficiency at investment in organization capital), or entrepreneurial motivation and objectives. All explanations are by necessity speculative. It is, of course, possible that chief executives selected to head state-owned enterprises are simply less qualified or experienced than their counterparts in the private sector. We have shown that differences in initial organization capital, however, can explain only differences in level but not in rates of growth of firm-specific productivity measures. Also, a presumption of systematic differences in production parameters (including productivity at investment in organization capital) in one direction may be erroneous since state-owned enterprises may enjoy a superior level of specific technological parameters and factor prices (such as airports served, assigned routes, and borrowing costs) due to government protection and subsidization. In the following analysis we therefore focus on possible differences in entrepreneurial constraints and entrepreneurial or corporate objectives as underlying sources of differences in efficiency.

State-owned enterprises are not subject to the disciplinary forces of a private capital market in which privately-owned firms are continuously traded. No such organized exchanges are available to monitor the performance of state-owned enterprises nor do they typically operate under the same profit constraints as their private counterparts. It is thus reasonable to expect that chief

executives of the latter enterprises will devote a differentially higher amount of their entrepreneurial resources to obtain approval and recognition of their performance from the political bureaucracy. Moreover, being political appointees, top managers in public enterprises may seek to build for themselves some independent political capital, in addition to creating organization capital for their respective enterprises, assuming the two are not perfectly correlated.

The existence of productive uses for entrepreneurs' time and other resources outside of the enterprise, regardless of the specific nature of such objectives, would lead to reduced allocation of total entrepreneurial time to productive pursuits within the enterprises they serve: An interior solution for the general time allocation problem would inevitably imply a lower than maximum allocation of entrepreneurial time to the latter pursuits. The specific consequences of this result can be traced through the following modification of the analysis in sections B and C.

Let the Hamiltonian function (5.b) incorporate "investment in independent political capital" as an additional profitable pursuit for "state" entrepreneurs:

(18) $v(t) = A[K^{\alpha}L^{\beta}(HM)^{\gamma}]^{\eta} - wL - cI^{a}L^{-b} + \mu(I-\delta K) + \lambda bH(\bar{M}-M) + f(1-\bar{M})$,

where $\bar{M}$ and $1-\bar{M}$ denote the fraction of total entrepreneurial time devoted to productive pursuits inside and outside of the firm, respectively, and M and $\bar{M}-M$ denote, as before, the fractions of entrepreneurial time devoted to directing current production and to investment in new organization capital. It can easily be shown that as long as the entrepreneurial return from "politicking", $f(1-\bar{M})$, is an additive term in equation (18), the thrust of the dynamic equilibrium solutions of the model remains the same as that discussed in sections B and C. The steady-state rate of growth in organization capital, however, is now given by

(19) $\hat{H} = \{(r\bar{M}-\rho)[(1/\eta)-\alpha/(a-b)-\beta]\}/[(1/\eta)-\alpha/(a-b)-\beta-\gamma]$,

if the firm is a monopoly (for the competitive firm $\eta=1$).

Clearly, equation (19) is identical to equation (15.b) for the monopoly or equation (15) for the competitive firm except that the internal rate of return to investment in organization capital is now found to be proportional to the fraction of managerial resources devoted to internal pursuits within the firm.

Proposition 6: Differences in ownership can result in differences in both levels and rates of TFP growth across firms through different allocations of entrepreneurial inputs to productive pursuits within the respective firms.

The proof follows directly from equation (19) as $\partial\hat{H}/\partial\bar{M} > 0$. Since any interior optimum solution of the time allocation problem associated with the Hamiltonian function (18) implies that $0 < \bar{M} < 1$, the fraction of entrepreneurial time allocated to the state enterprise would fall short of unity (its magnitude in privately owned firms), and, consequently, the rate of accumulation of organization capital in state-owned enterprises would also be smaller. This result links differences in type of ownership not just to the level of firm productivity, but to the latter's rate of growth as well.

D.2. Ownership and Allocative Efficiency

State-owned enterprises may be required to obey a corporate objective function that is dictated by the political establishment and deviates from pure profit maximization. Such objectives may include, for example, a political preference for labor employment (cf. Bös (1986)). In that case, the Hamiltonian function (5.b) may be written

(20) $v(t) = v_1(t) + \sigma\phi(L)$,

where $v_1(t)$ denotes the R.H.S. of equation (5.b). The only change in the first-order optimality conditions associated with this system concerns the optimization condition for labor employment which becomes

(21) $\beta R/L + \sigma\phi'(L) = w$,

where $\phi'(L) = d\phi/dL$. Now if $\phi(L)$ is a linear function of L, all the growth

equilibrium conditions derived in section C and B would obtain in this case as well.[6]

Proposition 7: If the state enterprise's objective function included a linear "preference" function for labor, there would be no change in the steady state rate of growth of output and TFP. Such preferences would affect, however, the firm's chosen factor intensities in production, and thus the level of its cost curve.

While the solution for $\hat{H}$, and thus for the level and rate of growth of TFP, remains the same as that expressed in equation (15b), equation (21) indicates a higher optimal labor to capital ratio in the state enterprise relative to their profit-maximizing ratio. Ceteris paribus, such allocative inefficiency must result in a higher level of unit cost of output in state enterprises.

Allocative inefficiencies stemming from different objective functions in state-owned enterprises that are mandated by the state are thus seen to affect only the level of the firm's unit costs and its rate of return on capital, but not its productivity growth over time. Consequently, these effects may not present any long-term problem of survival for state-owned enterprises even in a purely competitive system where firms face identical production possibilities, assuming the state is willing to provide a constant level of subsidization per unit output. Technological inefficiencies due to the effect of ownership on the incentive to accumulate organization capital, in contrast, do present a more severe problem of survival for state-owned enterprises since they affect the rate of growth of total factor productivity and thus the rate of decrease in unit costs and the rate of increase in output. Since productivity growth in state enterprises lags behind that in privately owned firms, any downward trend in prices as a result of an industry-wide increase in total factor productivity would affect adversely the viability of the state-owned enterprise by requiring increasing government subsidies per unit output over time to insure its survival.

II. Empirical Implementation

A. The Data Set and Key Variables

The empirical analysis is conducted using data on 23 airlines from 18 countries over the period 1973-1983. These airlines were chosen on the basis of data availability from a larger set selected so as to ensure a balance between private, mixed and state ownership, and approximate comparability in important airline characteristics. In particular, of the airlines in our sample eight can be viewed as state-owned, seven as mixed,[7] and eight as private. They are distributed geographically as follows: 5 in North America, 11 in Europe, 4 in the Far East, 2 in South Asia and one in Brazil. The airlines were selected to have at least 50% of their traffic on international routes, at least a half-million ton-kilometers flown annually and an average stage length of at least 1,000 km, or 700 km in the case of SAS.

The data, which are described in detail in the accompanying Appendix, are mostly from the International Civil Aviation Organization. In particular, the ICAO reports employment, investment, cost of materials, cost of fuel, fleet composition, revenue by four output categories, physical output by category, number of cities served, average stage length, and passenger load defined as the ratio of seat miles sold over seat miles flown. From other specialized sources, we collected the government's share of equity and aviation fuel prices. Robert Windle of the University of Maryland was kind enough to share his data on lease prices by category of aircraft, ground property and equipment service prices, and expenditure deflators for materials and for ground property and equipment for the different countries in the sample. These data have been reported in Caves, Christensen, Tretheway and Windle [CCTW] (1984) and are not described in detail here. Key points about the data are first, that the lease price information by standardized type of airplane represents a potentially important improvement in the measurement of the user cost of capital, and in that sense

we believe that we have efficient data with which to explore the determinants of variations in total factor productivity and costs across the various airlines. Second, the price deflators for ground property and equipment and materials are constructed using the Kravis, Summers and Heston (1975) purchasing power parity indices by product category, so that problems related to imperfections in exchange rates should be minimized. Other items such as fleet and fuel costs as well as all revenues are converted to dollars at market exchange rates, since all airlines conduct their business in the international aviation market. Labor costs are converted to dollars at market exchange rates.

The measurement of the enterprise's type of ownership is a critical issue of concern for our study. Previous studies have tended to rely on a categorical variable based on some arbitrary criterion for distinguishing private and public ownership. To avoid reliance on arbitrary criteria we use a continuous ownership measure defined as the percent of the airline's equity owned by the government. A more desirable measure would be the degree of control over resource allocation exercised by the government in the various airlines, but we cannot estimate this directly. Indeed, our continuous ownership variable may be a poor proxy for the desirable control measure, especially if the latter were discontinuous in ownership at a critical ownership level. We try to account for the general measurement problem, first, by allowing for a nonlinear effect of ownership in the various regressions we conduct. This is accomplished by introducing our ownership measure in both a linear and quadratic form and by using a logarithmic transformation of ownership. We also attempt to account for the degree of control exercised by the private capital market by distinguishing firms that are traded from those that are not traded in a private capital market. Nonetheless we also convert our continuous variable to a categorical measure of ownership choosing breakpoints of 15% and 85%, respectively, (see footnote 7) in order to test the sensitivity of the analysis to the use of a continuous variable.

To measure productivity we use a multilateral translog Tornqvist index associated with Christensen and Jorgenson (1970), and Jorgenson and Nishimizu (1978), and which has earlier been used to study airlines by Gillen, Oum and Tretheway [GOT] (1984). This index, described in detail by Diewert, (1976), and more specifically in the Appendix, is exact for a second-order approximation of any twice differentiable linearly homogeneous production. It is essentially a ratio of aggregate output to aggregate input. Output is the weighted sum of each type of output and the weights are the revenue shares. Aggregate input is the weighted sum of the individual inputs, and the weights are each input's share of total cost. For this study, both the TFP index and the output index which we use in the cost function have several limitations. Both indices essentially measure differences in quantities and in composition, and neither appropriately corrects for changes in quality even when these are reflected in prices. To see this, suppose that secular improvements in human capital result in greater productivity of physical labor. Then its wage and its cost share both rise, but the shares of other inputs fall, so only the change in composition is reflected in the index of inputs, and hence in the productivity index itself. Thus our index of TFP does not net out the effects of secular improvement in human capital or in the quality of capital inputs of newer vintages. We attempt to control for these problems first by including firm dummies, which in the context of our sample of 23 firms in 18 countries behave very much like country dummies, and then by including as regressors both real domestic product per capita and an interaction term defined as the product of real GDP and trend. The firm dummies serve to capture unobserved and omitted variables which are specific to an individual firm or country, and remain constant over time. Their inclusion has been shown by Mundlak (1961, 1978) to reduce the omitted variable bias in the estimation of the effects of the included variables. Real GDP is included as a proxy for the level of human capital in workers and the level of exogenous

disembodied technology, both of which contribute to high levels of GDP. The interaction of GDP with time is included to capture any correspondence between general rates of productivity growth and the overall level of development.

The assumption of linear homogeneity underlying use of the TFP index is consistent with the findings of other researchers, notably Caves, Christensen and Tretheway [CCT] (1984), CCTW, and GOT, who have all found constant returns to scale using data primarily from the U.S. or Canada. Our cost function analysis of international data indicates that the international airline industry may be characterized by increasing returns to scale, as well as by increasing returns to density, and so appears to be at odds with the findings of the other researchers. The difference could be attributable to the presence of government regulation and barriers to entry in the international marketplace which are absent from the North American market. Another distinct possibility, however, is that the difference in the estimates of returns to scale results from our use of different data for airports, the key variable in distinguishing returns to density from returns to scale. We use ICAO data on traffic by cities in order to measure the number of aiports, while CCTW have data on airports served. These measures should correspond except when airlines serve multiple airports in the same city, and this difference may partially explain our finding of increasing returns to scale. In the presence of increasing returns to scale, our TFP measure can be interpreted only as a residual measure, (of output growth after accounting for a proxy measure of input growth) and not as a measure of technological efficiency.

Unlike the TFP index, the translog function specification we use in section C is free of any restrictions concerning the degree of homogeneity of the production function. However, its estimation is subject to limitations similar to those affecting the TFP analysis if the quality of inputs and outputs are subject to cross-country variations or secular trends. We thus include in the

cost regressions the same set of corrections we include in the TFP regressions to account for unobserved firm or country-specific influences. Note that in both the TFP and cost function regressions, secular improvements in, say, input qualities that are common to all airlines are captured by the time-trend effect, and thus its magnitude does not reflect a pure firm-specific productivity growth. However, the ownership trend interaction term we include as a separate variable in all regressions should produce an unbiased estimate of the effect of ownership on the rate of firm-specific productivity growth, or cost decline, since it accounts for systematic deviations from the common trend due to firm ownership.

B. Total Factor Productivity

Given the well-known power of the cost functions that we estimate in the following subsection, we wish to explain the rationale for our separate TFP analysis. It provides a) a separate identification of technical efficiency, and b) some protection against any unidentified problems associated with the exchange rates used to standardize our cost data, since the TFP measurement involves only physical inputs and outputs, and cost and revenue shares.

We analyze the effect of ownership on TFP levels by including the percent of equity owned by the state as a regressor in both linear and quadratic form. The general rate of growth of TFP, after accounting for the effects of technical variables mentioned below, is estimated by the coefficient of the time trend introduced as a separate regressor. To measure the effect of ownership on TFP growth we include an interaction term defined as the product of the time trend and the percent of equity belonging to the state. The annual trend rate of growth of TFP is thus defined as a linear function of ownership, the slope of which is the coefficient of the time-ownership interaction.

We conduct OLS regressions relating the logs of the TFP measure to ownership and ownership squared, a time trend and a time-ownership interaction, dummy variables for the individual firms, and a set of technical variables,

including the number of airports served, average stage length, and passenger load. These technical variables have been shown in some studies to influence cost, so we consider also their effects on TFP. We include the log of the output index as a regressor in an effort to attribute part of the TFP variation to economies of density, although spurious correlation between these variables may lead to an overestimate of any economies of density. The TFP regressions are reported in Table 1.

In regression 1, all the technical variables are included and the effect of state ownership on the level of productivity is strongly negative and nonlinear. From the parameter estimates for the linear and quadratic ownership terms we may calculate that the TFP is between 160% and 180% lower in the 100% state-owned firms than in the firms that are entirely private. This number varies but little in the various regression models that we have studied[8] which include ownership as a continuous variable. The rate of growth of TFP for the private firms is 0.96%, while the effect of state ownership on the trend rate of growth (.016%) in TFP is negative and significant at the 99.9% confidence level. This coefficient implies that the rate of growth of TFP in firms which are 100% state-owned is 1.6 percentage points lower than in firms which are entirely private. Over the eleven years of our sample, this results in a 19% difference in productivity. Alternatively, it means that the difference in productivity between private and state enterprises doubles every 43 years. Although both the output effects and the airport effects are significantly different from zero, the average stage length and the passenger load all have t-ratios less than 1.1. When these two technical variables are deleted, as in regression 2, the effects of ownership on both the level and the rate of growth of the residual are little changed.

In regression 3 we add the log of the real gross domestic product per capita as measured by Summers and Heston (1988) in order to proxy for those

Table 1

Total Factor Productivity Regressions
Parameter Estimates and Standard Errors in ( )

	(1)	(2)	(3)	(4)	(5)
Intercept	2.124 (0.594)	2.259 (0.558)	-2.510 (1.361)	2.273 (0.559)	0.737 (0.181)
Output	0.42660 (0.04237)	0.41085 (0.03851)	0.307 (0.0494)	0.417 (0.0395)	0.383 (0.0400)
Airports	-0.101 (0.0468)	-0.117 (0.0444)	-0.136 (0.0432)	-0.120 (0.0446)	-0.0955 (0.0461)
Stage-Length	-0.103 (0.0947)				
Passenger Load	-0.0332 (0.135)				
Ownership	-0.0457 (0.0127)	-0.0471 (0.0125)	-0.0389 (0.0122)	-0.0475 (0.0125)	
Ownership^2	0.00028 (0.000076)	0.000291 (0.0000749)	0.000234 (0.0000737)	0.000296 (0.0000753)	
Time-Ownership	-0.000164 (0.0000424)	-0.000162 (0.0000412)	-0.000175 (0.0000448)	-0.000159 (0.0000410)	
Time	0.00964 (0.00488)	0.00866 (0.00395)	0.07999 (0.0266)	0.00790 (0.00410)	
GDP			0.500 (0.132)		
Time-GDP			-0.00810 (0.00270)		
Time-Output				0.001999 (0.00285)	
Mixed					-0.524 (0.702)
State					-0.463 (0.0688)
Time					0.0142 (0.00418)
Time-Mixed					-0.00977 (0.00471)
Time-State					-0.0182 (0.00430)
Firm Dummies	Yes	Yes	Yes	Yes	Yes
No. of Observations	234	234	234	234	234
R^2	0.951	0.950	0.954	0.950	0.947

factors such as general human capital, disembodied innovation, and culture, which are exogenous to the firm. If a proxy for such factors is excluded, and they correlate with state ownership, then the estimates of the effects of state ownership on TFP may be biased. As explained in section A, we also include in this model an interaction term defined as the product of time and the log of GDP. In regression 3 the time-GDP interaction is negative and significant at the 99.9% confidence level, while GDP has an elasticity of .5 and a standard error of .13. The effects of the other variables are unchanged, and the significance of the trend effect is preserved. Thus the time ownership interaction appears remarkably robust to alternative model specifications, despite a very high degree of collinearity among the regressors.

In regression 4, we consider an implication of an alternative approach to productivity growth, by which the latter is generated through "purchased" process innovation within the firm (see our discussion of Proposition 2 in section I). If such innovation uses some fixed costs independent of scale, such as the purchase of a new design, or the employment of a designer, then larger firms should have more process innovation and productivity growth than smaller firms. This specification differs from the one we develop in section I above. We explore this idea by including an interaction term defined as the product of time and the log of output. This term is positive but insignificant in a regression otherwise identical to regression 2, so that we can reject the importance of scale on TFP growth.

Regression 5 uses dummy variables for the mixed and state categories, instead of the continuous ownership variable. Mixed and state firms have TFP levels 52% and 46% lower than the private firms, and the differences in the rate of TFP growth are significant and similar to the other regressions.

Finally, we investigate whether the effects of output and the number of airports, and then output, airports, stage length and load factor, are the same

across different types of ownership. First, we divide the sample into the three subsets, of our ownership categories: private, mixed and state (see footnote 7). The resulting F test for homogeneity of the subsets yields values of 1.27 for regression 2, with output and airports, and 2.22 for regression 1, with output and all three technical variables, so that at traditional confidence levels we can reject the hypothesis that the effects of the technical variables on TFP differ by type of ownership.[9]

C. Cost Functions

Our cost functions are estimated using the by-now conventional method pioneered by Berndt and Wood (1975), and Christensen and Greene (1976). Christensen and Greene applied Shephard's Lemma to a translog cost function to derive input share equations which are jointly estimated with the cost function, subject to restrictions of linear homogeneity of the cost function in input prices and equality of theoretically identical coefficients in the cost and input share equations. The translog form is a second order approximation of any general cost function. We follow convention by estimating the regression using second order terms defined as one half the square of the log of the regressor, for all regressors except ownership. Since all regressors are normalized by sample means prior to estimation, the first order terms are interpretable as the elasticities evaluated at the sample means. CCT, CCTW, and GOT have applied these cost estimation techniques to airlines largely to assess the consequences of deregulation in the U.S. and in Canada.

Table 2 contains estimates of several regressions chosen to show the robustness of the effect of ownership on cost levels and rates of decline, as well as to explore related hypotheses about technological change. All of these regressions include firm dummy variables which perform similarly to country dummies, as in our TFP regressions. In addition, all regressions include interaction terms between ownership and prices to reflect the hypothesis

Table 2
Total Cost Functions*
Parameter Estimates and Standard Errors in ( )

	(1)	(2)	(3)	(4)	(5)
Intercept	-.680 (.205)	-.753 (.214)	.768 (1.263)	-.692 (.205)	-.0321 (.0595)
Labor Price	.245 (.00606)	.241 (.00570)	.245 (.00610)	.244 (.00604)	.237 (.00593)
Fuel Price	.204 (.00475)	.201 (.00448)	.204 (.00472)	.204 (.00476)	.197 (.00468)
Capital Price	.551 (.00807)	.558 (.00797)	.551 (.00809)	.552 (.00805)	.566 (.00791)
Output	.630 (.0558)	.640 (.0554)	.648 (.0628)	.708 (.0638)	.634 (.0633)
Airports	-.0948 (.0546)	-.0705 (.0527)	-.114 (.0604)	-.136 (.0567)	-.123 (.0617)
Ownership	.150 (.0450)	.168 (.0454)	.148 (.0530)	.151 (.0449)	
Time-Ownership	.00305 (.000801)	.00259 (.000819)	.00148 (.00101)	.00331 (.000806)	
Time	-.0264 (.00759)	-.0262 (.00834)	.0722 (.0290)	-.0317 (.00795)	-.0275 (.00852)
Capital-Labor Price	-.0786 (.00814)	-.0829 (.00803)	-.0825 (.00771)	-.0785 (.00808)	-.0723 (.00797)
Capital-Fuel Price	-.0347 (.00728)	-.0529 (.00747)	-.0379 (.00701)	-.0327 (.00732)	-.0340 (.00719)
Labor-Fuel Price	-.0441 (.00401)	-.0381 (.00396)	-.0419 (.00388)	-.0452 (.00400)	-.0462 (.00396)
Labor Price^2	.123 (.00659)	.121 (.00636)	.124 (.00627)	.124 (.00654)	.119 (.00652)
Fuel Price^2	.0788 (.00502)	.0910 (.00521)	.0798 (.00494)	.0779 (.00505)	.0802 (.00507)
Capital Price^2	.113 (.0132)	.136 (.0133)	.120 (.0125)	.111 (.0133)	.106 (.0129)
Output-Labor Price	-.0271 (.00453)	-.0240 (.00426)	-.0278 (.00451)	-.0270 (.00450)	-.0255 (.00444)
Output-Fuel Price	.0223 (.00343)	.0210 (.00324)	.0216 (.00339)	.0234 (.00345)	.0228 (.00342)
Output-Capital Price	.0048 (.00610)	.0030 (.00594)	.00620 (.00604)	.00360 (.00608)	.00270 (.00599)
Output^2	-.0188 (.0296)	-.0141 (.0291)	.0453 (.0361)	.0789 (.0475)	-.0221 (.0337)

7/a

	(1)	(2)	(3)	(4)	(5)
$Time^2$	.00108 (.00107)	.00118 (.00107)	-.000856 (.00122)	.00165 (.00110)	.000487 (.00118)
Labor Price-Airports	.0371 (.00641)	.0308 (.00602)	.0372 (.00645)	.0363 (.00639)	.0298 (.00642)
Fuel Price-Airports	-.0189 (.00497)	-.0201 (.00468)	-.0189 (.00495)	-.0194 (.00498)	-.0253 (.00501)
Capital Price-Airports	-.0182 (.00849)	-.0107 (.00837)	.0183 (.00851)	-.0169 (.00847)	-.00450 (.00853)
$Airports^2$	-.125 (.0603)	-.149 (.0615)	-.146 (.0657)	-.133 (.0604)	-.168 (.0673)
Airport-Output	-.0533 (.0302)	-.0482 (.0304)	-.0322 (.0341)	-.0885 (.0329)	-.0682 (.0330)
Capital Price-Ownership	-.00272 (.00234)	-.00403 (.00236)	-.00292 (.00234)	-.00297 (.00233)	
Labor Price-Ownership	.00293 (.00178)	.00224 (.00171)	.00303 (.00179)	.00313 (.00177)	
Fuel Price-Ownership	-.00021 (.00135)	.00179 (.00131)	-.000109 (.00134)	-.000164 (.000135)	
GDP			-.150 (.131)		
Time-GDP			-.00944 (.00282)		
Time-Output				-.00963 (.00374)	
Stage Length		.102 (.0882)			
Passenger Load		.0596 (.157)			
Labor Price-Stage Length		-.0546 (.00853)			
Fuel Price-Stage Length		.0193 (.00656)			
Capital Price-Stage Length		.0353 (.0119)			
Labor Price-Load		-.0653 (.348)			
Fuel Price-Load		-.154 (.0284)			
Capital Price-Load		.219 (.0495)			
Mixed					.351 (.0733)
State					.496 (.0727)

	(1)	(2)	(3)	(4)	(5)
Mixed-Labor Price					.0306 (.00914)
Mixed-Fuel Price					.0182 (.00706)
Mixed-Capital Price					-.0488 (.0121)
State-Labor Price					.0168 (.00797)
State-Fuel Price					.000935 (.00616)
State-Capital Price					-.0177 (.0105)
Time-Mixed					.0172 (.00472)
Time-State					.0144 (.00400)
Firm Dummies	Yes	Yes	Yes	Yes	Yes

*In this table state ownership is entered in log form.

elaborated in Section 1, (footnote 6), that optimizing state-owned firms may take as given a shadow price of labor which is lower than the market wage by an amount related to the extent of state ownership. Since we impose restrictions consistent with Shephard's Lemma, the coefficient of an interaction term between the price of an input j and another regressor is interpreted as the effect of the other regressor on the cost share of input j.

In general, the direct effect of state ownership on the level of costs is negative and significant with 99.9% confidence. The effect of ownership on the rate of technical progress is also negative and significant at the 99.9% confidence level. Thus, state ownership appears to slow cost declines. Both of these effects were anticipated by Proposition 6 in section I above. The effect of ownership on labor demand, i.e., labor's cost share, is positive but significant only at the 90% confidence level. This weaker evidence of allocative effects associated with state-ownership is consistent with the existence of a government preference for labor employment in state enterprises, as anticipated by Proposition 7 in section I. In the first regression, which excludes the stage length and passenger load regressors, we show the importance and statistical significance of static and dynamic technical inefficiencies, as well as allocative effects. To measure the static effects we take the coefficients of ownership and ownership squared to calculate that the percentage increase in static unit cost (from either technical or allocative inefficiency) associated with a one percentage point increase in state ownership is (0.0303-2(.000191) ownership), i.e., 1.1% when state ownership is 50 and 3% when state ownership is nil. To contrast pure private ownership with pure state ownership note that for the latter, the gross ownership effect is (.0303ownership-.000191(ownership^2) = 1.12. In the regressions using ownership in linear and quadratic forms, the effect of nationalization on the level of costs varies from 73% to 112%. The quadratic term is significant at the 99%

confidence level and this suggests one possible explanation for the sometimes ambiguous effect of ownership on productivity that has been claimed in some of the studies surveyed by Borcherding (1982): excluding the quadratic term reduces the significance and magnitude of the first-order term.

The ownership-time interaction is positive and significant at the 99.9% confidence level. The magnitude, 0.000176, implies that the annual rate of cost decline drops by .0176% with an increase of one percentage point in state ownership. Comparing the 100% state-owned firm with a private firm, the rate of cost decline of the latter will be 1.76 percentage points greater than for the former. This is a relatively large difference in growth rates, which in the 11 years of our sample aggregates to a 21% cost difference, all of which must be attributable solely to dynamic technical inefficiencies, given our model. This dynamic inefficiency implies that the production costs for the "representative" state firm will double relative to those of its private counterpart in a span of 40 years.

The effect of state ownership on labor's share is found to be positive, (.000116), and is significantly different from zero at only the 90% confidence level. In the regression involving dummy variables for the mixed and state categories, labor's share of total cost was higher for mixed than for private with 99% confidence, and it was higher for state than for private with 95% confidence. Thus we have some evidence that the state-owned firms may be allocatively inefficient due to the selection of wrong factor proportions.

The inclusion of the number of airports as a regressor again permits a distinction between economies of scale and economies of density first emphasized by Caves, Christensen and Tretheway (1984). They define the former as $1/(\epsilon_Q+\epsilon_P)$ and the latter as $1/\epsilon_Q$, where ϵ_Q is the elasticity of total cost with respect to output and ϵ_P is the elasticity of total cost with respect to airports served. Using the first-order terms to calculate returns to density at the sample mean

gives $1/\epsilon_Q = 2.0$, indicating strong returns to density. The returns to scale is $1/(\epsilon_Q+\epsilon_P) = 1.88$ with a standard error of .075 so that at conventional confidence levels we can reject the hypothesis of constant returns to scale. These results differ from CCT in both the output effect and the airport effect. Using only U.S. data they find .804 and .132 respectively, while we find .50 and .31 respectively. As stated in subsection II.A. above, however, we cannot view this finding as conclusive evidence for increasing returns to scale in international air transport because of the quality of the "airports served" measure that we use.

The first regression excludes two variables sometimes shown to be important in airline cost estimation: average stage length, and the passenger load factor. In our sample, as in some earlier studies, these effects are mostly insignificant as is illustrated in regression 2.

In the third regression we add the Summers and Heston (1988) real GDP data in log form and its interaction with time to correct for the effect of factors such as human capital, disembodied innovation and "culture" on productivity levels and rates of growth as we have done in the TFP regressions. After correcting for these possibilities, the effects of ownership on the level and rate of decline of cost are all still significant, and the latter is even larger in magnitude. Indeed, the effect of ownership on the rate of cost decline has increased more than 50% in magnitude with the inclusion of these variables.

In the fourth regression, we consider the effect of scale on cost declines by including an interaction term defined as the product of time and the log of output. Its effect is significantly different from zero only at the 90% confidence level. Thus, we find little indication that some type of process innovation other than that specified in our model may be operative.

The fifth regression is identical to the first except that the ownership variables are replaced with dummies for the mixed and state ownership categories.

In this case the cost increases associated with moving from private to mixed and private to state are about 53%, and significant at the 99.9% level. Each of the interactions between time and each of these dummies is about 2.1%, and significant at the 99.9% confidence level. The similarity of the behavior of the mixed and the state relative to the private ownership categories suggests that the inefficiencies associated with government ownership may appear even when the government owns relatively small percentages of equity, although sufficient to assume control.

A final question involves whether the effects of an airline's network characteristics differ by type of ownership. In particular, do the effects of scale, density, stage length, and loading differ between private and state enterprise? We consider this question by including interaction terms between ownership and each of the variables for scale, airports, stage length, and loading. In this regression none of the interaction terms between ownership and the technical variables is significant, and the level and rate effects of ownership remain essentially unchanged. Thus we cannot reject the hypothesis that these structural effects are independent of ownership.

Conclusion

We have shown that the type of ownership of a firm can affect the rate of growth of firm-specific productivity and not just its level. This effect of ownership was derived from a model of self-generating productivity growth at the firm level in which organization capital is the engine of growth and its rate of accumulation is dictated by the fraction of entrepreneurial resources that is allocated to productive activities benefitting the enterprise, as opposed to external activities imposed by the political system. Our empirical investigation reveals that the difference in rate of cost decline between private and state-owned airlines is 1.76% annually or about 21% during the 11 years of our sample.

Very similar estimates of differences in the rate of decrease of production cost: are revealed through our independent estimation of the airlines' cost functio over the sample period. On the basis of our theoretical analysis and th corroborative evidence from our TFP and cost function estimation we ascribe th differences in the rates of change of productivity and production costs t differences in technical efficiency by ownership. We find weaker evidence, however, for differences in allocative efficiency by ownership due to a bia toward labor employment in state enterprises. The latter inefficiency ma contribute to the observed differences in the level of production costs acros enterprise types in our regressions. We estimate that the privatization o state-owned enterprises may lower the level of production costs by as much a 53%.

These results may understate the true effects of differences in ownershi both on the level and rate of growth of firm-specific productivity because o sample selection biases. Since the most inefficient state firms are the one most likely to become privatized, the airlines that persist as state-owned ove our sample period should be those which enjoy productivity growth greater tha the true mean level of all state-owned airlines.

Our results are constrained by several important limitations. First, th total factor productivity measure we use and our cost function estimates cannot account for changes in the quality of individual input categories due to economy-wide growth of human capital and technological innovations. We have tried to account for such external influences on productivity by accounting for country-specific effects and the static and dynamic effects of gross domestic product per capita. These corrections in fact strengthen our results concerning this role of ownership on economic efficiency.

Second, although we are interested in determining the effects of government control of firms on static and dynamic efficiency indicators, we have only data

on the percent of equity belonging to the government in the various airlines we compare, which may be an imperfect measure of control. We have experimented, however, with alternative ownership definitions and specifications and found the results to be largely insensitive to the specification of the ownership variable.

Third, we have no direct test of the multiple objectives of the entrepreneurs of the state enterprises, which is key to our explanation of productivity differences.

Last, our model and empirical analysis ignore the possible role of labor unions in firms of different types of ownership, although the latter may be important in explaining the apparent government "preference" for labor.

Our theoretical model and empirical results, however, in part answer earlier questions raised by Lucas (1988) and others about the mechanism through which government policies may affect the rate of growth of productivity, rather than just its level. The analysis suggests that government control of economic resources may affect the dynamic as well as static efficiency of their use. These dynamic effects, if shown to be comparable to the ones we ascribe to state ownership of firms in this study, may provide important insights into the role of government in economic development.

FOOTNOTES

1 It seems plausible that the marginal cost of adjustment depends in some way on the scale of investment relative to the stock of existing capital, rather than on the former alone (i.e., b=0 in (4)). Otherwise, if a firm is in a steady-state growth equilibrium, the adjustment cost level would ultimately approach an infinite magnitude as time goes to infinity. This specification is consistent with Lucas' (1967) specification of a "general" adjustment cost function. Its advantage in the context of the present analysis is that it is compatible with a steady-state growth equilibrium whereby the ratio of capital to labor or output may remain constant over time (see equation (13)).

2 The solution for the steady-state level of entrepreneurial time allocated to directing current output is given by

$M^* = \{(\rho/r)[1-(\alpha(a-b))-\beta]-\gamma\}/\{1-[\alpha/(a-b)]-\beta-\gamma\}$. For a numerical illustration of the solutions for $\hat{H}$, $\hat{Q}$ and M^* let $r=.03$, $\rho=.02$, $\alpha=.03$, $\beta=.6$, $\gamma=.05$, and $a-b=1$. Then $\hat{H}=.02$, $\hat{Q} = .01$, and $M^*=.34$.

3 Substituting equation (13) in equation (11) the latter becomes

$\lim_{t\to\infty} K_0\mu_0 e^{(g-\rho)t} = 0$, which can be fulfilled iff $g < \rho$.

4 If the level of demand itself is subject to positive growth, however, due to economy-wide growth in productivity, equation (15.b) below becomes

(15.c) $\hat{H} = \{(r-\rho)[(1/\eta)-(\alpha/(a-b))-\beta]+(\hat{A}/\eta)\}/\{(1/\eta)-[\alpha/(a-b)]-\beta-\gamma\}$.

The rate of total factor productivity growth will be higher the higher rate of increase in demand, $\hat{A}$, and output prices need not then decline over time.

5 In the general case where we allow the level of demand to be subject to a constant rate of increase $\hat{A}$ (see (fn.3), the relationship between the rates of growth of output and TFP is given by the linear function

$\hat{Q} = \{\gamma\hat{H} + \hat{A}[(\alpha/(a-b))+\beta]/\{(1/\eta)-[\alpha/(a-b)]-\beta\}$,

and that between the rates of growth of profits and output by $\hat{\pi} = \eta\hat{Q}+\hat{A}$. Thus profit margins rise or fall with output depending upon whether $\hat{A}-(1-\eta)\hat{Q} \gtreqless 0$. The rate of return on capital, however, is still given by the constant term $i^*(t) = \pi_o / \mu_o K_o$, as in section I. B.

6 Note that if $\phi(L)$ is not a linear function in L, however, the balanced growth condition for labor employment $\hat{R} - \hat{L} = \hat{w} \geq 0$ no longer holds, and an explicit solution of the system becomes intractable. In the empirical implementation of the model we further specialize $\phi(L)=wL$ so that the preference for labor can be viewed as an implicit ad-valorem subsidy on the rental price of labor at which the firm minimizes its production costs. The correspondence between the firm's cost and factor-demand function is preserved under this assumption.

7 We define mixed airlines as those with between 15 and 85% of their equity owned by the government. In our data a natural breakpoint exists at 15% while above 70% there is a more or less continuous distribution. Alitalia and Singapore Airlines are both classified as mixed in some years and state in others.

8 From the linear and quadratic effects we may calculate that the minimum of TFP occurs where the state ownership is about 80% of equity. We test and reject the hypothesis that the marginal effect of ownership on TFP is non-positive at a state ownership level of 100, given that the relation is quadratic. The fact that this extreme occurs at ownership levels less than 100% is suggestive of how imperfectly our ownership variable measures government control.

9 If we use the unpooled regressions and test the significance of the differences in trend effects between the different regressions we find the same results.

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