Workine Paper 8813

DECOMPOSING TFP GROWTH IN THE PRESENCE OF COST INEFFICIENCY, NONCONSTANT RETURNS TO SCALE, AND TECHNOLOGICAL PROGRESS

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December 1988

ABSTRACT

Productivity growth is a major source of economic growth; thus, an understanding of how and why productivity measures change is of great interest to economists and policymakers. This paper explores the relationship between observed total factor productivity (TFP) growth, defined using an index number approach, and examines changes in returns to scale, cost efficiency, and technology. Several decompositions are developed, using alternatively production and cost frontiers. The last decomposition developed also allows for multiple outputs.

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I. Introduction

Measures of productivity have long enjoyed a great deal of interest among researchers analyzing firm performance and behavior. The observed growth in total factor productivity (TFP) is one of the most widely employed measures of overall productivity. The conventional Divisia index of TFP is defined as[1]

(1) $\dot{TFP} = \dot{y} - \dot{F}$, where

(2) $\dot{F} = \sum_i \frac{w_i x_i}{C} \dot{x}_i$,

where y is observed output, F is an aggregate measure of observed input usage, w_i is the price of the i-th input, x_i is the observed use of the i-th input, and C is the observed cost.[2]

Ohta (1974) and Denny, Fuss, and Waverman (1981), among others, have shown that in the single-product case, with constant returns to scale and cost efficiency, TFP growth equals technological progress. With nonconstant returns to scale and cost efficiency, TFP growth is equal to technological progress plus a term that adjusts for the degree of returns to scale:

(3) $\dot{TFP} = \dot{f}(x,t) + (\epsilon_{cy}^{-1}-1)\ \dot{F}$,

where f is the production function, x is the vector of inputs, t is a time index, and ϵ_{cy} is the cost elasticity with respect to output.

This paper extends the decomposition of observed TFP growth by showing how changes in cost efficiency over time also affect the observed measure of TFP growth. The observed measure of TFP is decomposed into various components roughly stemming from changes in returns to scale, in cost efficiency, and in technological progress. Biased estimates of firm or industry performance will result if changes in cost efficiency are ignored. Furthermore, since these decompositions are derived from an observed quantity, the appropriate decomposition could be included in the estimation of the frontier as an additional equation, thus improving the statistical precision of the estimates by providing additional information and increasing the number of degrees of freedom.

In section II of this paper, TFP growth is decomposed using a production function approach. Section III derives the decomposition using a cost function approach for both the single-product and multiproduct firm. Section IV presents some empirical examples of the use of some of these decompositions, and the conclusion appears in Section V.

II. Production Function Approach

Let the production frontier be defined as

$$(4) \qquad y^* = f(x,t),$$

where y^* is the maximum amount of output that can be produced with input vector x at time t.

A Farrell-type, output-based measure of technical efficiency can be defined as follows:

$$(5) \qquad T_p = \frac{y}{f(x,t)}, \text{ where } 0 < T_p \leq 1.$$

The first TFP decomposition can be derived as follows. First, take the natural log of both sides of (5) and totally differentiate it with respect to time:

$$(6) \quad \frac{d\ln T_p}{dt} = \frac{d\ln y}{dt} - \sum_i \frac{\partial \ln f(x,t)}{\partial x_i} \frac{dx_i}{dt} - \frac{\partial \ln f(x,t)}{at}.$$

This can be rewritten as

$$(7) \qquad \dot{T}_p = \dot{y} - \dot{f}(x,t) - \sum_i \frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)} \dot{x}_i,$$

where $\dot{T}_p$ is the time rate of change of technical efficiency and $\dot{f}(x,t)$ is the time rate of change of technological progress as measured by shifts in the production frontier over time.

Next, (7) can be rearranged using the definition of observed TFP in (1):

$$(8) \qquad T\dot{P}F = \dot{T}_p + \dot{f}(x,t) + \sum_i \left(\frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)} - \frac{w_i x_i}{C} \right) \dot{x}_i.$$

The following substitutions can be made:

$$(9) \qquad \epsilon_i(x,t) = \frac{\partial f(x,t)}{\partial x_i} \frac{x_i}{f(x,t)}, \text{ and}$$

$$(10) \qquad s_i = \frac{w_i x_i}{C},$$

where $\epsilon_i(x,t)$ is the output elasticity of the i-th input and s_i is the observed share of the i-th input. This yields the following decomposition:

$$(11) \qquad T\dot{F}P = \dot{T}_p + \dot{f}(x,t) + \sum_i [\epsilon_i(x,t) - s_i]\ \dot{x}_i,$$

which decomposes observed TFP growth into change in technical efficiency, technological progress, and a term that depends on the degree of the input-specific returns to scale and cost inefficiency.[3] This decomposition yields the intuitive result that advances in both technological progress and technical efficiency increase observed TFP growth. While the first two terms have straightforward interpretations, the last term requires further explanation.

This term has two informative properties. First, under cost efficiency, this term is equal to the last term in (3) , since cost minimization requires

$$(12) \qquad \frac{\partial f}{\partial x_i} = \frac{w_i}{\left(\frac{\partial C}{\partial y}\right)}, \text{ for all i.}$$

Second, when the firm is cost inefficient, this last term is a bundle composed of nonconstant returns to scale and both technical and allocative inefficiency. One can further decompose this term using duality; however, the cost function approach developed in the next section does this in a much more straightforward manner. But first, consider the relation between this decomposition and that of Nishimizu and Page (1982).

Nishimizu and Page derived their decomposition as follows. First, they define what might be called the "average" production function, $g(x,t)$, as

$$(13) \qquad y = g(x,t).$$

In contrast to the frontier production function, $f(x,t)$, the observed production function yields what each firm actually produces. They transform (13) by taking the natural logarithm and totally differentiating with respect to time to obtain

$$(14) \qquad \dot{g}(x,t) = \dot{y} - \sum_i \epsilon_{gi}(x,t)\, \dot{x}_i,$$

where $\epsilon_{gi}(x,t)$ is the output elasticity of the i-th input with respect to the "average" production function.

Nishimizu and Page then employ an alternative approach to defining TFP. Instead of defining TFP with respect to a Divisia index, they define TFP with respect to the rate of shift in the "average" production function, $\dot{g}(x,t)$.[4]

The next step in deriving their decomposition is to rewrite equation (7) as

$$(15) \qquad \dot{y} = \dot{T}_p + \dot{f}(x,t) + \sum_i \epsilon_i(x,t)\, \dot{x}_i.$$

Substituting for y in (14) and simplifying yields

$$(16) \quad \dot{g}(x,t) = \dot{f}(x,t) + \dot{T}_p + \sum_i \left[\epsilon_i(x,t) - \epsilon_{gi}(x,t) \right] \dot{x}_i .$$

This is the Nishimizu and Page decomposition; equation (16) separates observed TFP growth into technological progress, change in efficiency, and differences in output elasticities between the frontier and the interior for a firm operating in the interior. While (16) is quite similar in form to (11), there are two important differences.

First, it must be recalled that Nishimizu and Page employ a different definition of TFP than the one employed here. They define it to be the rate of shift in the "average" production function, whereas the decompositions derived here are based on a definition of observed TFP using the Divisia index. The potential advantage of the latter approach is that it creates the possibility of adding another equation to the system to be estimated (in addition to the cost and input share equations) since the left side of equation (11) is observed and the right side of equation (11) is a function of the parameters to be estimated.[5] Including the TFP equation in the regression increases the number of degrees of freedom (since no new parameters are added) and also provides information that is not found in the cost or input demand equations.

Second, the use of an "average" production function, $g(x,t)$, may be of use conceptually, given Nishimizu and Page's assumption that firms operating away from the frontier have a good reason for doing so. This is not useful empirically, however, because $g(x,t)$ cannot be estimated simultaneously with the frontier production function unless the reason for the deviation from the frontier is also modeled. Without this type of modeling, the only possible definition of $g(x,t)$ is

$$(17) \qquad g(x,t) = f(x,t) \cdot T_t.$$

This implies that their "average" production function models not only the frontier production function, but also inefficiency. In other words, it predicts the level of inefficiency--with the same arguments as the frontier production function. The cost function TFP decompositions are now derived.

III. Cost Function Approach

The TFP decomposition is first derived in the case of the single-product firm and is then generalized for the multiproduct firm. Let the single-product cost frontier be represented by

$$(18) \qquad C^* = C(y,w,t),$$

where C^* is the efficient cost given (y,w,t). Following Farrell (1957), an overall measure of cost efficiency may be defined as

$$(19) \qquad E = \frac{C(y,w,t)}{C}.$$

From these input-based measures of technical and allocative efficiency, one can derive

(20) $E = T \cdot A$, which implies

(21) $\dot{E} = \dot{T} + \dot{A}$, (which will be used later),

where T and A are the Farrell measures of technical and allocative efficiency, respectively.

The decomposition of TFP growth can now be derived using the cost function approach. Taking the natural logarithm of each side of (19), totally differentiating, and making a few minor substitutions yields

$$(22) \qquad \dot{E} = \epsilon_{cy}(y,w,t)\ \dot{y} + \sum_i \frac{\partial C(y,w,t)}{\partial w_i} \frac{w_i}{C(y,w,t)}\ \dot{w}_i + \dot{C}(y,w,t) - \dot{C},$$

where $\epsilon_{cy}(y,w,t) = \frac{\partial \ln C(y,w,t)}{\partial \ln y}$. Using the definition of observed TFP in equation (1), equation (22) can be simplified as follows:

$$(23) \qquad \dot{TFP} = \left[1-\epsilon_{cy}(y,w,t)\right]\ \dot{y} + \dot{E} - \dot{C}(y,w,t) - \sum_i \frac{w_i x_i(y,w,t)}{C(y,w,t)}\ \dot{w}_i$$

$$- \sum_i \frac{w_i x_i}{C}\ \dot{x}_i + \dot{C}.$$

At this point, note the following:

$$(24) \qquad C = \sum_i w_i x_i,$$

$$(25) \qquad \frac{dC}{dt} = \sum_i w_i \frac{dx_i}{dt} + \sum_i x_i \frac{dw_i}{dt},$$

(26) $$\dot{C} = \sum_i \frac{w_i x_i}{C} \dot{x}_i + \sum_i \frac{w_i x_i}{C} \dot{w}_i, \text{ and}$$

(27) $$\sum_i \frac{w_i x_i}{C} \dot{x}_i = \dot{C} - \sum_i \frac{w_i x_i}{C} \dot{w}_i .$$

Substituting (27) into (23) yields

(28) $$\dot{TFP} = \left[1-\epsilon_{cy}(y,w,t)\right] \dot{y} + \dot{E} - \dot{C}(y,w,t) + \sum_i \left[\frac{w_i x_i}{C} - \frac{w_i x_i(y,w,t)}{C(y,w,t)} \right] \dot{w}_i .$$

Substituting (21) into (28) and making some straightforward substitutions yields the single-product cost function decomposition of observed TFP:

(29) $$\dot{TFP} = \left[1-\epsilon_{cy}(y,w,t)\right] \dot{y} + \dot{T} + \dot{A} - \dot{C}(y,w,t) + \sum_i \left[s_i - s_i(y,w,t) \right] \dot{w}_i .$$

This expression decomposes TFP growth into terms related to returns to scale, changes in technical and allocative efficiency, technological progress, and a residual term (which will be discussed below). This decomposition is consistent with expectations; in particular, the expectation that increases in cost efficiency increase observed TFP.

The last term clearly reflects the presence of allocative inefficiency. If the firm is allocatively efficient, then $s_i = s_i(y,w,t)$, and this term is equal to zero. This term is also equal to zero when input prices change at the same rate, since $\sum_i [s_i - s_i(y,w,t)] = 0$. Some insight into this term can be obtained by noting that in the presence of allocative inefficiency, since the observed input shares, s_i, are not equal to the efficient input shares, $s_i(y,w,t)$, the aggregate index of input usage F (used to define observed TFP) does not weight the observed inputs according to the cost-minimizing input shares. The last term corrects for any bias this may have on observed TFP.

A multiproduct version of the decomposition can also be derived. For the multiproduct firm, observed TFP is usually defined as[6]

$$\text{(30)} \qquad \text{TFP} = \dot{y}^P - \dot{F}, \text{ where } \dot{y}^P = \sum_j \frac{p_j y_j}{R} \dot{y}_j \text{ and } F = \sum_i \frac{w_i x_i}{C} \dot{x}_i,$$

where y^P is a revenue-weighted index of output, F is a cost share index of aggregate input usage, w_i is the price of the i-th input, x_i is the observed use of the i-th input, and C is the observed cost.

Using the same basic steps used in the single-product case above for handling cost inefficiency and in Denny, Fuss, and Waverman (1981) for handling multiple outputs, observed TFP for a multiproduct firm can be shown to be equal to the following:

$$\text{(31)} \qquad \dot{\text{TFP}} = \left[1 - \sum_j \epsilon_{cy_j}(y,w,z,t) \right] \dot{y}^c + \dot{T} + \dot{A} - \dot{C}(y,w,z,t)$$

$$+ \sum_i \left[s_i - s_i(y,w,z,t) \right] \dot{w}_i + (y^P - \dot{y}^c), \text{ where } y^c = \sum_j \left[\frac{\epsilon_{cy_i}}{\sum_j \epsilon_{cy_j}} \right] \dot{y}_j .$$

This expression decomposes TFP growth into terms related to ray returns to scale, changes in technical and allocative efficiency, and technological progress. The next-to-last term has the same properties as the last term in equation (25). The last term simply measures any effect that nonmarginal cost pricing may have on the observed measure of TFP. Denny, Fuss, and Waverman have shown that $y^p = y^c$ under marginal cost pricing and proportional markup pricing.

These TFP decompositions provide useful conceptual and empirical tools for assigning the observed changes in TFP growth to the various root sources. Note that the cost function approach provides a more complete partitioning of the sources of observed TFP growth than the production approach did.

IV. Empirical Application

This section illustrates a use of one of the multiproduct TFP decompositions. The example is drawn from the U.S. airline industry, and these results are discussed more fully in Bauer (1988). First, the model that was estimated and the data set that was employed are briefly discussed; then the empirical results and the TFP decomposition are presented.

The translog system of cost and input share equations that was estimated is presented below (omitting firm and time subscripts):

$$(32) \quad \ln C = \ln C(y,w,z,t) + u + v$$

$$= \beta_o + \sum_i \beta_{y_i} \ln y_i + \sum_i \beta_{w_i} \ln w_i + \beta_{ldf} \ln z_{ldf} + \beta_{stgl} \ln z_{stgl} + \beta_t t$$

$$+ 1/2 \sum_i \sum_j \beta_{y_i y_j} \ln y_i \ln y_j + \sum_i \sum_j \beta_{y_i w_j} \ln y_i \ln w_j$$

$$+ 1/2 \sum_i \sum_j \beta_{w_i w_j} \ln w_i \ln w_j + u + v,$$

(33) $$s_i = s_i(y,w) + \omega_i$$

$$= \beta_{W_i} + \sum_i \beta_{y_j} \ln y_j + \sum_j \beta_{w_i w_j} \ln w_j + \omega_i, \; i = 1,\ldots,M,$$

where y is a vector of outputs, w is a vector of input prices, z is a vector of network characteristics, and t is a time index. The translog functional form was selected on the basis of its being a second-order approximation to any cost function about a point of expansion (here, the sample means).[7] Note that the network and time variables were not interacted with input prices in order to reduce the number of parameters to a manageable level and to lessen the effects of multicollinearity. Symmetry and linear homogeneity in input prices impose the following restrictions on the cost system:

(34) $$\beta_{w_i w_j} = \beta_{w_j w_i}, \; \sum_i \beta_{w_i} = 1, \; \sum_j \beta_{w_i w_j} = \sum_j \beta_{y_i w_j} = 0, \; \forall \; i,j.$$

By construction, $\sum_i s_i(y,w)=1$, so that one input share equation must be dropped before estimation to avoid singularity. Barten (1969) has shown that asymptotically, the parameter estimates are invariant as to which input share equation is dropped.

The following distributional assumptions are imposed. The inefficiency term, u_{nt}, is assumed to follow a truncated-normal distribution with mode μ and underlying variance σ_u^2 such that $u_{nt} \geq 0$. The noise term, v_{nt}, is assumed to be independent of u_{nt} and to follow a normal distribution with mean zero and variance σ_v^2. The disturbances on the input share equations are assumed to follow a multivariate normal distribution: $\omega_{nt} = (\omega_{1nt},\ldots,\omega_{M-1,nt})' \sim N(\alpha,\Omega)$.

The likelihood function for this system can be written as[8]

$$
\begin{aligned}
(35)\quad \ln L = & - \frac{TNM}{2}\ln(2\pi) - \frac{TN}{2}\ln\sigma^2 - \frac{TN}{2}\ln|\Omega| \\
& - \frac{1}{2\sigma^2}\sum_t\sum_n (\ln C_{nt} - \ln C(y_{nt},w_{nt},z_{nt},t) - \mu)^2 \\
& + \sum_t\sum_n \ln[1-F^*(\sigma^{-1}(-\frac{\mu}{\lambda} - (\ln C_{nt} - \ln C(y_{nt},w_{nt},z_{nt},t))\lambda))] \\
& - (TN)\ \ln[1-F^*((-\frac{\lambda}{\sigma})(\lambda^{-2}+1)^{1/2})] - \frac{1}{2}\sum_t\sum_n (\omega_{nt}-\alpha)'\ \Omega^{-1}\ (\omega_{nt}-\alpha).
\end{aligned}
$$

Maximum likelihood estimates can be obtained for all the parameters in (35), and these estimates will be asymptotically efficient. A number of specification tests can be performed using likelihood ratio tests similar to those proposed by Stevenson (1980).

The data set employed in this paper was constructed by Robin Sickles using the AIMS 41 form that all interstate airlines were required to submit periodically as part of the Civil Aeronautics Board's regulation of the industry. Included are 12 firms and 48 quarters of data from 1970:IQ to 1981:IVQ. The airline industry is considered to produce revenue passenger ton miles (y_p) and revenue cargo ton miles (y_c) using four inputs: labor (L), capital (K), energy (E), and materials (M). Labor is an aggregate of 55 separate labor accounts; capital is a combination of flight equipment, ground equipment, and landing fees; energy is the quantity of fuel used converted to BTU equivalents; and materials is an aggregate of 56 different accounts composed mainly of advertising, insurance, commissions, and passenger meals.[9]

The network through which airlines supply their outputs has an important influence on the cost of providing that output. The average load factor, z_{ldf}, for a given airline in a given time period is the proportion of an airline's capacity that is actually sold in that time period. The average stage length, z_{stgl}, is the average distance of an airline's flights in a given quarter. These two network characteristics are incorporated into the two translog cost models as presented in equation (32).

From table 1 it can be seen that all but two of the parameter estimates are statistically significant. The parameters reported here are from a model slightly more restricted than the one developed in section III. Instead of the more general truncated-normal distribution, the half-normal distribution was assumed, which is equivalent to restricting $\mu=0$. This restriction could not be rejected using a t-test based on the results of the more general model.

Table 2 reports the results of the TFP decomposition technique. Observed TFP grew on average for all of the firms, although there was a great deal of variation across firms. Much of this increase is the result of technological progress that ran at a rate of 0.274 percent per quarter, as reported earlier. The scale effect was a significant source of TFP gains for the smaller airlines, which were free to grow under the regulatcry reform process, but not for the four largest airlines. The inefficiency effects varied considerably from airline to airline, but were generally small. Over time, changes in the airlines' networks have generally boosted productivity. The average load factors and stage lengths of the airlines have risen (although unevenly across airlines), each resulting in increases in observed TFP of about the same order of magnitude as those stemming from technological progress.

The biases in the observed measure of TFP as a result of nonmarginal cost pricing (the output effect) and observed input shares not being equal to the least-cost input shares (the price effect) are found to have a small effect on observed TFP. A "pure" measure of TFP growth could be constructed by summing the scale, cost efficiency, technological change, and network effects. In general, these estimates indicate that the observed measure of TFP is a biased estimate of technological progress, not just because of the scale and output effects (as Denny, Fuss, and Waverman have shown), but also because of the efficiency, network, and input price effects.

V. Conclusion

Observed TFP growth has been decomposed into scale, change in efficiency, and technological progress effects using both production and cost function approaches for both single-product and multiproduct firms. The production function approach was compared to the decomposition of Nishimizu and Page (1982) and was found to have at least the possible advantage that the observed TFP equation might be added to the system of equations to be estimated. In addition, the decomposition derived here does not depend on the artificial construction of an "average" production function. In this respect, the decomposition proposed here seems to be more firmly based in cost theory and efficiency measurement.

The decompositions of TFP developed here will have at least two uses in empirical work. First, there is the potential that the TFP equation could be added to the system of equations to be estimated. Since this equation provides information not contained in the others and increases the number of degrees of freedom, better estimates of technology (as embodied in the production or cost function) and the level of cost efficiency will be obtained. Second, it will also be of use in interpreting and explaining empirical results. For example, TFP growth has been negative in some industries in recent years--a fact that is sometimes difficult to explain in a framework that does not allow for cost inefficiency (see Gollop and Roberts [1981]). Using this decomposition, negative TFP growth could turn out to be a result of declines in cost efficiency, both technical and allocative.

Footnotes

[1] Variables with a dot over them are defined as follows: $\dot{z} = \frac{d\ln z}{dt}$.

[2] See Jorgenson and Griliches (1967), Richter (1966), Hulten (1973), Diewert (1976), and Denny, Fuss, and Waverman (1981), among others, for uses of this definition.

[3] Returns to scale can be defined as follows: RTS $= \sum_i \epsilon_i(x, t)$.

[4] For a discussion of the various approaches to defining TFP growth, see Diewert (1981).

[5] Exactly how to implement this potential advantage both econometrically and practically has not yet been solved.

[6] See Denny, Fuss, and Waverman (1981).

[7] Though the translog functional form is a second-order approximation of the cost function at a point, it is generally only a first-order approximation of the economic measures of technology derived from the cost function. For example, note that the observed input shares are only a linear function of the regressors, being the first derivative of the log of the cost function.

[8] Strictly speaking, it is incorrect to model the disturbances in the cost and input share equations as being independent, given the interdependence of $\partial \ln A_{nt}/\partial \ln w_{int}$ and u_{nt}. However, as Schmidt (1984) pointed out, these terms will tend to be uncorrelated, since both negative and positive deviations from efficient shares raise costs.

[9] For a more detailed description of this data set see Sickles (1985).

Table 1

MLE Parameter Estimates

Parameters	Estimate	Asymptotic Standard Error
$\sqrt{\sigma}$	0.328961	0.011959
$\sqrt{\lambda}$	1.136091	0.142654
β_o	19.368848	0.036376
β_{y_p}	0.855741	0.013566
β_{y_c}	0.140263	0.013380
β_K	0.099889	0.015654
β_L	0.469013	0.043650
β_E	0.232090	0.024935
β_{ldf}	-0.663032	0.041049
β_{stgl}	-0.292790	0.020772
β_t	-0.002744	0.001055
$\beta_{y_p y_p}$	0.085471	0.019229
$\beta_{y_p y_c}$	-0.121785	0.028829
$\beta_{y_p K}$	-0.036898	0.003079
$\beta_{y_p L}$	0.044412	0.004507
$\beta_{y_p E}$	0.006407	0.002081
$\beta_{y_c y_c}$	0.061784	0.012200
$\beta_{y_c K}$	0.030902	0.002478
$\beta_{y_c L}$	-0.040931	0.003587
$\beta_{y_c E}$	0.005638	0.001655
$1/2\beta_{KK}$	-0.001860	0.002050*
β_{KL}	0.019602	0.003266
β_{KE}	-0.019293	0.001967
$1/2\beta_{LL}$	0.050961	0.005694
β_{LE}	-0.063920	0.005064
$1/2\beta_{EE}$	0.061453	0.000928
α_K	0.087048	0.015658
α_L	-0.061833	0.043642*
α_E	-0.021023	0.024930*

*Not statistically significant at the 0.01 level of significance.

Source: Author's calculations.

Table 2

TFP Decomposition
(Average quarterly rate of change, in percent)

Airline	TFP	Scale Effect	Output Effect	Eff. Effect	Technical Change	Price Effect	Load Factor	Stage Length
AA	0.7195	-0.0189	0.0686	0.0063	0.274	-0.1270	0.3584	0.1578
AL	1.3782	0.2140	-0.0626	0.1945	0.274	-0.0976	0.4873	0.3682
BR	0.5067	0.0377	0.1717	-0.0294	0.274	-0.0814	0.0041	0.1297
CO	0.4529	0.0517	0.1058	0.0261	0.274	-0.1101	-0.0017	0.1066
DL	0.3665	-0.0109	0.0011	0.0180	0.274	-0.0632	0.0093	0.1378
EA	0.4613	-0.0174	0.0085	0.0489	0.274	-0.1216	0.2038	0.0648
FL	1.1749	0.2108	-0.0817	0.0435	0.274	-0.1497	0.4287	0.4490
NC	1.8818	0.4639	-0.0385	0.1132	0.274	0.0098	0.4256	0.6335
OZ	1.0371	0.2694	-0.0417	0.0717	0.274	-0.1033	0.0492	0.5175
PI	1.4081	0.3548	0.0116	-0.0256	0.274	-0.0225	0.3069	0.5086
UA	0.5864	-0.0284	0.0430	-0.0576	0.274	-0.1400	0.3020	0.1931
WA	0.6202	0.0483	-0.0237	-0.0317	0.274	-0.1120	0.3249	0.1342
Avg.	0.8723	0.1317	0.0148	0.0308	0.274	-0.0937	0.2303	0.2835

Source: Author's calculations.

The key to the carrier abbreviations are as follows:

American	AA	Continental	CO	Frontier	FL	Piedmont	PI
USAir	AL	Delta	DL	North Central	NC	United	UA
Braniff	BR	Eastern	EA	Ozark	OZ	Western	WA

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