THE PRODUCTIVITY PERFORMANCE OF THE CANADIAN AIRLINE INDUSTRY

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Introduction

Productivity generally measures the efficiency in which an economy or enterprise turns inputs into outputs (Baldwin and Gu, 2010). Growth in productivity, that is producing more with the same amount of input, or producing the same output with less input, is one of the key drivers of economic growth.

Canada as a whole has been criticized for a lack of productivity growth and this remains a topic of concern for policy makers (Rao, 2011). In the overall economy the transportation industry plays an integral role, moving intermediate inputs to production points and final goods for resale and consumption as well as moving passengers for business and leisure activities.

The Economic Analysis division of the Centre of Excellence in Economics, Statistics, Analysis and Research (CEESAR) at Transport Canada has been estimating the productivity of major Canadian transportation carriers since 1981. Their productivity program includes estimates for rail, trucking and air modes of transport. Though efforts were made to encompass as much of the industry as possible, the previous structure utilized a static carrier aggregation procedure. Specifically for the air carrier industry only a subset of the available carriers were used in the analysis and adding new entrants and eliminating carriers that had ceased to operate was cumbersome and prone to human error.

The focus of the current analysis is to build on the previous structure of the productivity program and incorporate a dynamic carrier aggregation methodology that encompasses the entire Canadian airline industry each year. This dynamic approach will incorporate airline carriers into the aggregation in proportion to their share of the total activity in the industry. Estimates of partial productivity and total factor productivity will be presented for the period 1988 to 2010.

Views expressed in this paper benefited from exchanges between the authors and colleagues from Transport Canada. The author thanks all reviewers of this article for their useful comments. However, the views expressed herein do not necessarily reflect those of Transport Canada. This paper represents a summary of a larger methodological document. Questions can be directed to the author.

Data Overview

The data for this analysis is sourced from Transport Canada's internal Electronic Collection of Air Transportation Statistics (ECATS) program. Every commercial air carrier operating in Canada is required to submit statistics to Transport Canada and Statistics Canada. The data include operational statistics such as the amount of passengers or kilograms of freight transported, as well as financial and balance sheet information. The data was originally collected under the Air Carrier Operations in Canada (Statements 10, 12, 20, 21) survey from Statistics Canada.

Sector Overview
Though the Canadian airline industry is dominated by a few major carriers it is also quite dynamic with carriers entering and leaving the market over time. For example, there were 263 carriers in 1988 that submitted data, while only 102 carriers submitted in 2010.

The majority (81%) of industry revenues for the last 22 years have been derived from scheduled passenger transportation, followed by chartered passenger transportation. Freight transport accounts for less than 10% of total air carrier revenues.

Output Estimation Methodology

For this analysis output is segmented into the following categories: Passenger, Freight, Scheduled, Chartered, Domestic and International movements. To produce an annual time series of aggregated output quantities total nominal industry revenues will be deflated by a weighted price index, as suggested by the Bureau of Labor Statistics (2012).

The price index will take into account price changes across the different categories of airline output by aggregating each component using a translog multilateral index (or Tornqvist index) approach first proposed by Caves et al. (1982) and also used in the airline analysis by Oum and Yu (1995). There are several steps to this procedure.

The first step is to compute the price received, or yield, that the carrier receives for providing the transport service. This is calculated as revenue per passenger kilometre or tonne-kilometre, depending on which type of movement between passenger or freight transport. The yield must be adjusted to take into account the different operating stage lengths for the various carriers. A stage length is the distance flown between an origin and destination. As suggested by Hamlin (2012), because fixed operating costs per flight, i.e. fuel burn for taxiing and take-off, contribute a higher proportion of the total cost for a shorter stage length the yield charged for those shorter flights will be relatively higher in order to cover those fixed costs.

Given that some carriers engage in short stage lengths as their primary business operation, an adjustment formula is used to adjust all yields to an unbiased unit of measurement. The following formula for standardizing yield outlined by the MIT airline data project is utilized:

$$\widetilde{Y_{ighk}} = \left[\sqrt{\frac{X_{ighk}}{\overline{X}_{ghk}}} \right] \cdot Y_{ighk}$$

(1)

Where,

$\widetilde{Y_{ighk}}$ is the standardized yield for carrier i, movement type g, service h, and sector k,

X_{ighk} is the observed stage length for carrier i, movement type g, service h, and sector k,

$\overline{X}_{ghk}$ is the average stage length for the movement type g, service h, and sector k,

Y_{ighk} is the observed yield for carrier i, movement type g, service h, and sector k.

This adjustment formula standardizes yields and accounts for the difference in stage lengths for each carrier and service.

The second step, once yields are determined, is to estimate the annual change in prices using the Tornqvist aggregation method. As outlined in Caves et al. (1982) this is a procedure that compares each service yield against the previous year's yield in log percentage change and the total change in yields for the year is simply the weighted sum of the individual percentage changes. Each service is weighted by its share of total revenue. This share is determined by taking the average proportion of total revenues which that category of service represents for that year and the year before. Following Duke and Torres (2005) it is represented using the following formula:

$$P_T = \sum_{ighk} \left[S_{ighk} * \left(LN\left(\widetilde{Y_{ighk}}\right)^T - LN\left(\widetilde{Y_{ighk}}\right)^{T-1}\right)\right]$$

(2)

Where,

P_T is the sum of the weighted yield changes,

T is the time period,

$\widetilde{Y_{ighk}}$ is the standardized yield for carrier i, movement type g, service h, and sector k,

S_{ighk} is the share of revenues for carrier i, movement type g, service h, and sector k, which is determined by:

$$S_{ighk} = \frac{1}{2} * \left[\left(\frac{R_{ighk}^T}{\sum_{ighk} R_{ighk}^T} \right) + \left(\frac{R_{ighk}^{T-1}}{\sum_{ighk} R_{ighk}^{T-1}} \right)\right]$$

(3)

Where,

R_{ighk}^{T} is the revenue for carrier i, movement type g, service h, and sector k in time T.

Once the weighted natural log price changes have been aggregated an index is built by setting 1988 as the base year and multiplying each year's exponential to the previous year to produce a chained index. This process can be seen below with the formula:

$$I_T = EXP(P_T) * I_{T-1}$$ (4)

Where,

I_T is the price index for time T,

P_T is the sum of the weighted natural logs of the yield differences.

After the output price index has been derived the last step to estimate total industry output quantities is to divide the annual total nominal industry revenues by the computed price index value for that year.

Results
The estimation procedure outlined above provided the following results (Please see the appendix table for a summary of results). For the 22 year period prices have increased 26.6%, for a compound annual growth rate (CAGR) of 1.1% and a standard deviation of 5.9%. Output has increased 108.6% for a CAGR of 3.4% and a standard deviation of 8.0%. Prices increased the fastest during the 1990 to 1995 sub-period at an average rate of 2.3% per year, while ouput and revenue increased the fastest during the 1995 to 2000 period at 7.9 and 9.9%, respectively.

Input Estimation Methodology

Overview
This analysis uses four major input categories to estimate the productivity of the airline industry. The categories are Labour, Energy, Capital (composed of leased and owned capital) and an

Intermediate category comprising all other inputs. This section will detail the methodology used to derive an input quantity index for each input and will detail results as partial productivity measures. A later section of this analysis will detail the methodology and results for combining all of the inputs together into a weighted index to estimate a total factor productivity measure.

Labour

Wages were the second largest input utilized by airlines. There were approxiametly 50,000 employees in the industry in 1988 and roughly the same number in 2010. Employment was also highly variable in the industry, including a large contraction beginning in 2001. This is believed to be largely due to the outsourcing of aircraft servicing personnel by one of the large carriers.

Labour Quantity Estimation Methodology
Following Scheppach and Woehlcke (1975), in order to account for the year to year changes in the composition of labour this factor is divided into six sub-categories and aggregated using a translog multilateral indexing procedure. The weighting and aggregation method follows the same procedure as previously used for estimating the output price index, utilizing equations (1) and (2) to produce a compositionally weighted index of employment changes. The weights for the index are the share of wages for an employment category as a proportion of total wages.

The categories of labour input were pilots, flight personnel, administration staff, maintenance, aircraft servicing personnel and an "other" category of labour. As detailed above, the change in quantity of employees in each category is weighted in the tornqvist indexing procedure by its share of the total wage expense for the year. Outlined in Scheppach and Woehlcke (1975), this procedure helps to account for shifts in labour composition as well quality of labour.

Labour Estimation Results
Labour productivity has grown 111.1% from 1988 to 2010, for a compound annual growth rate of 3.5% and a standard deviation in

annual growth rates of 9.2%. The fastest period of growth for labour productivity was from 2000 to 2005 at 9.4%, while the slowest growth period was from 2005 to 2010 at 1.7%.

Energy Quantity Estimation Methodology

The two primary sources of energy in the airline industry are aviation gasoline used by propeller-powered aircraft and aviation jet fuel used by jet engine powered aircraft. In order to create a single measure of total energy use, as in Gillen, Oum and Tretheway (1990), the two fuels are converted into their energy equivalent based in terajoules. One mega litre of aviation gas contains 33.52 terajoules of energy, while one mega litre of aviation jet fuel contains 37.40 terajoules of energy (Statistics Canada, 2009). The two are then combined to form an annual energy amount that is indexed to the amount used in 1988 and this level is set to 100.0.

Energy Estimation Results
Energy use increased 28.7% from 1988 to 2010. The highest growth rate in energy use was seen during the 1995–2000 time period at an annual average of 4.6%. This corresponds with the highest growth rate in output during that time. Energy productivity for the period improved 62.1%, with major improvements during the 2000 to 2005 time period.

Capital

Given the complexity of estimating the capital stock of an industry, there are many steps in the process. First, distinction is made between leased and owned capital.

Owned Capital Quantity Estimation Methodology
Theoretically, the perpetual inventory method from Christensen and Jorgenson (1969) is used to estimate the use of capital, where the amount of use is determined to be a proportion of the actual stock of capital. The formula is shown below:

$$K_{it} = I_{it} + (1 - d_i)K_{i,t-1} \tag{5}$$

Where,

K_{it} is the real capital stock of category i in time t
I_{it} is the investment in capital stock in time t
d_i is the depreciation rate of the category of capital stock in time t.

For owned capital the first step is to estimate the stock of capital of the physical assets, including land and equipment. Land assets are segmented out of total assets in order to estimate separately and then are aggregated back into owned capital. The amount of land capital expenditures out of total expenditures is estimated by multiplying *the average ratio of land to total assets* for the airline industry to the *gross value of total assets*. This provides a measure of the land stock for a given year.

By taking the difference between the previous year's land value and the current year's land value we get an estimate of the net change in land stock and assume that the difference is the amount expended on the land category. For example, if the difference in land value is positive then more was invested in land than was depreciated for that year, and vice versa if the difference is negative. This estimate of land expenditures is then deflated by a land price index to determine the quantity amount that was added to the land stock per year.

After the value of land is calculated it is subtracted out of net operating assets in order to calculate the rest of the capital stock. Capital price indices are derived from Statistics Canada data by taking the ratio between current and constant dollar estimates for capital in the airline industry. Investment in physical units (and not dollars) is estimated by taking the difference in those assets each year and deflating by the capital price index. This provides an estimate of the quantity of the capital stock invested. The net capital stock then represents the original capital stock plus physical investment minus depreciated quantities (see equation 5).

The initial stock of assets for 1988 was estimated by taking the ratio of the net stock of capital in original dollars to constant dollars for 1988 and applying it to the book value of total assets in that year. The

investment and depreciation rates were then applied to that initial capital stock and a time-series was constructed.

Leased Capital Quantity Estimation Methodology
Leased capital is the amount of capital that is not actually owned by the airlines, but still used in the production process. The quantity of leased capital used is derived by deflating the amount of aircraft rental expenditures by a rental price index derived below.

As was done in Transport Canada Economic Research (2004), to estimate the rental price index two indices are calculated, one for the price of the aircraft and one for the price of the funds to lease that aircraft. To estimate the price index for aircraft the ratio of current and constant dollar value estimates of that asset class are used. An exchange rate adjustment is also applied to this aircraft price index.

To estimate the cost of leasing the aircraft a formula for the annual repayment of a machine is used to estimate the required payment needed to finance the lease. This is from Kohn (1990) and can be seen below:

$$LC = P\left(\frac{i}{1-(i+1)^{-n}}\right)$$

(6)

Where,

        LC is the annual repayment (or lease) cost,
        P is the value of the rented or leased asset,
        i is the rate of interest or cost of funds,
        n is the service life of the asset.

Fluctuations in this annual leasing cost would indicate variations in the leasing price. The interest rate used is the corporate bond rate and the service life of the assets is from the Capital Stock division of Statistics Canada.

Once these two price indices have been estimated they are multiplied together to form an aggregate leasing price index. Aircraft rental

expenditures are then deflated by the price index to estimate a leasing quantity index.

Once the owned capital and leased capital indices are derived they are aggregated together in the same manner as the other inputs. The percentage change in both inputs for a given year is weighted by their share of the sum of their total cost and these are chained to produce a total capital quantity use index.

Results
Capital use increased 123.1% from 1988 to 2010, for a compound annual growth rate of 3.7% and a standard deviation of 14.0%. From 2000 to 2005 capital use was very erratic, increasing and decreasing substantially from year to year. The average growth rate of capital use during that period was 1.0% but the standard deviation was 15.1%.

The highly variable values may be a symptom of a merger of large airline companies around that time period, or an error in the source data. The values for flight equipment from a large carrier seem to be causing the discrepancy and are currently being investigated at the data source. Also, the aircraft rental expenditure category is highly variable and would affect the leased capital index, which is approximately half of the total expenditures on capital.

Capital productivity decreased 6.5% from 1988 to 2010 for a CAGR of -0.3% and a standard deviation of 12.0%. The strongest growth in capital productivity was seen from 2000 to 2005 with an average growth rate of 3.9%. The weakest growth period was from 1990 to 1995 with an average growth rate of 1.4%.

Intermediate Inputs

The Intermediate category of expenses makes up the rest of the operating expenses that have not been taken into account in the other inputs. Further segmentation of the Intermediate category is performed to try to be as detailed as possible. The nine categories of intermediate inputs are food, government fees, aircraft insurance, passenger insurance, other promotional expenses, advertising,

commissions, materials and supplies and an "other" category, which captures all other inputs.

Quantity Estimation Methodology
As in the Bureau of Labor Statistics Handbook of Methods (2012), the nominal expenses for each category are deflated by a price index to estimate input quantities. Using the appropriate price index removes the effect of price appreciation from their expenditures; therefore any variation in expenditures should only be due to quantity variation.

Government fees are deflated by a passenger index so that any variation in the expense is from the fees themselves and not from variations in passenger volumes. The passenger index is obtained using the output index methodology detailed in Section 1, but only passengers are included in the aggregation, variation in freight quantities are removed. Food, insurance and advertising are deflated by price indices obtained from a third party consultant firm. The "other" category of Intermediate expenses is deflated by a GDP deflator and the materials and supplies category is deflated by a GDP deflator adjusted for the exchange rate.

Estimation Results
Intermediate input quantities increased 30.3% from 1988 to 2010, for a compound annual growth rate of 3.7%. The highest average annual growth rate period was during the 1995–2000 period. Intermediate input productivity increased 60.1% over the study period, for a compound annual growth rate of 2.2%.

Total Factor Productivity

Quantity Estimation Methodology
With the quantity of individual inputs estimated and partial productivity estimates detailed earlier it is now possible to produce a total factor use index. Use is made of the translog multilateral indexing procedure detailed earlier, where the quantity of each of the four inputs is weighted by its share of the total cost of inputs for the current and preceding year.

The categories of input are labour, energy, capital and intermediate inputs. As detailed above, the change in quantity of an input in each category is weighted in the tornqvist indexing procedure by its share of the total cost expense for the year. Once the weighted natural log input quantities have been aggregated an index is built by setting 1988 as the base year and multiplying each year's exponential to the previous year.

With the weighted quantity of total inputs estimated and indexed, the total factor productivity is estimated by dividing the output quantity index by the input quantity index derived above.

Results
The total factor productivity of the airline industry increased 60.4% from 1988 to 2010, for a compound annual growth rate of 2.2% and a standard deviation in the growth rates of 6.2%. The period with the highest average growth rate was from 2000 to 2005 with a growth rate of 6.6% and the lowest growth rate was 1.3% from 1990 to 1995.

Conclusion

This analysis of the Canadian airline industry has estimated output prices and quantities for the 1988 to 2010 period using a dynamic carrier inclusion approach. Output quantities have grown at a much faster pace than output price growth. The analysis has shown that the labour productivity of the industry has grown given that employment has contracted and output has increased, but recently this trend shows signs of reversing. Energy productivity has also improved most likely as a reaction to the recent high price of that input. Capital productivity has been subpar and highly variable. Intermediate inputs are a major share of total inputs and the efficiency of their utilization has increased. The growth rate of the all factor inputs has been less than the output quantity growth, translating to growth in total factor productivity.

Appendix

Table 1. Various Productivity Indices

Index	Total Change 1988-2010	Average Annual Growth Rate					CAGR* 1988-2010	STD** 1989-2010
		1989 -2010	1990-1995	1995-2000	2000-2005	2005-2010		
Output Quantity Index	108.6	3.7	1.4	7.9	3.8	4.0	3.4	8.0
Output Price Index	26.6	1.2	2.3	2.1	-3.1	2.2	1.1	5.9
Total Input Index	30.1	1.4	0.1	5.8	-2.8	1.5	1.2	5.8
Energy Use Index	28.7	1.4	-0.1	4.6	-2.4	2.7	1.2	6.6
Labour Use Index	-1.2	0.2	-1.6	2.9	-5.1	3.0	-0.1	6.8
Intermediate Use Index	30.3	1.5	1.5	8.3	-2.9	0.4	1.2	7.8
Capital Use Index	123.1	4.5	0.4	4.4	1.0	3.5	3.7	14.0
Labour Productivity	111.1	3.8	3.0	5.0	9.4	1.7	3.5	9.2
Energy Productivity	62.1	2.3	1.6	3.3	6.3	1.2	2.2	4.9
Capital Productivity	-6.5	0.4	1.4	3.5	3.9	1.5	-0.3	12.0
Intermediate Productivity	60.1	2.5	0.2	0.1	7.0	3.7	2.2	8.1
Total Factor Productivity	60.4	2.4	1.3	2.2	6.6	2.4	2.2	6.2

*CAGR: Compound Annual Growth Rate, **STD: Standard Deviation

Bibliography

Baldwin, J., and Gu, W. (2008), Productivity: What is it? How Is It Measured? What Has Canada's Performance Been? Statistics Canada. URL: http://www.statcan.gc.ca/pub/15-206-x/15-206-x2008017-eng.pdf

Bureau of Labor Statistics: Handbook of Methods (2012), Chapter 11: Industry Productivity Measures. URL: http://www.bls.gov/opub/hom/

Caves, D.W, Christensen, L.R., and Diewert, E.W. (1982), Multilateral Comparisons of Output, Input, and Productivity using Superlative Index Numbers. Economic Journal, Vol. 92, March 1982.

Christensen, L.R., and Joregenson, D.W. (1969), The measurement of U.S. Real Capital Input, 1929–1967, Review of Income and Wealth, Series 15, No. 1, 293-320.

Coulombe, S. (2000), The Canada-U.S. Productivity Growth Paradox, Industry Canada Research Publications Program.

Duke, J., and Torres, V. (2005), Multifactor productivity change in the air transportation industry, Bureau of Labor Statistics Monthly Labor Review, Vol. 128, No. 3 March 2005.

Gillen, D.W., Oum, T.H., and Tretheway, M.W. (1990), Airline Cost Structure and Policy Implications: A Multi-Product Approach for Canadian Airlines, Journal of Transport Economics and Policy, Vol. 24, No. 1.

Hamlin, G.W. (2010), Adjusting Operating Cost for Segment Length, Airline Monitor, March/April, 2010.

Kohn, R. (1990), A Capital Budgeting Model of the Supply and Demand for Loanable Funds, Journal of Macroeconomics, Vol. 12, No. 3, 427-436.

MIT Data airline project. URL: http://web.mit.edu/airlinedata/www/2011%2012%20Month%20Documents/Revenue%20and%20Related/Total%20Revenue/Total%20Revenue%20(Ex-%20Transport%20Related)%20per%20Equivalent%20Seat%20Mile%20(TRESM%20ex%20Transport%20Related).htm

Oum, T.H., and Yu, C. (1995), A productivity comparison of the world's major airlines, Journal of Air Transport Management, Vol. 2, No ¾, 181-195.

Rao, S. (2011), Cracking Canada's Productivity Conundrum, Institute for Research on Public Policy. No. 25, URL:http://www.irpp.org/pubs/IRPPstudy/IRPP_Study_no25.pdf

Sharpe, A. (2010), Unbundling Canada's Weak Productivity Performance: The Way Forward, Centre for the Study of Living Standards. URL:http://www.csls.ca/reports/csls2010-02.pdf

Statistics Canada (2009), Report on Energy Supply and Demand, Manufacturing and Energy Division. URL: http://www.statcan.gc.ca/pub/57-003-x/57-003-x2009000-eng.pdf

Transport Canada Economic Research (2004), The Economic and Financial Performance of Transport Industries: The Airline Industry, Internal departmental document.