The Productivity Performance of the Canadian Airline Industry

A Dynamic Carrier Level Approach

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Summary

This analysis uses financial and operational data to compute aggregate input and output quantity indices for the airline industry in Canada for the years 1988 to 2010. These indices are combined to form partial productivity and total factor productivity estimates. Labour productivity for the industry has grown given that employment has contracted and output has increased. 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 and the estimation of the initial stock of capital has an impact on the growth rates in productivity. Intermediate inputs are a major share of total inputs and their productivity has increased. The total factor productivity of the sector has increased at a much faster rate than the inputs used to produce them.

Comparison of Transport Canada's productivity estimates with official estimates from Statistics Canada shows that the former depicts a much higher growth rate in total factor productivity than the later. This may be due to the aggregated industrial structure of the Statistics Canada estimates. At a more granular data level the comparison between Canadian and American airline sectors shows very similar rates of growth for output, input and total factor productivity, with the American sector showing slightly higher efficiency rates.

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1.0 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. As mentioned by Sharpe (2010):

"...Real incomes can only increase in the long run if more output is produced"

- Sharpe, (2010, pg. 10)

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 at Transport Canada (TCEA) has been estimating the productivity of Canadian major 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 this current analysis is to build on the previous structure of the productivity program at TCEA and incorporate a dynamic carrier aggregation methodology which 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 1988 to 2010 time period. Estimates derived here will also be compared against similar estimates produced by statistical agencies.

The rest of the paper is organized as follows. The second section will detail the source of the data and provide an overview of the operating environment of the airline industry in Canada. The third section will detail the output quantity estimation methodology and the results from the estimation. The fourth section will detail the input quantity estimation of four inputs: Labour, Energy, Capital, and an Intermediate category which encompasses remaining inputs not captured by the first three. Results from each estimation procedure will be presented in each subsection. The fifth section will compare the estimates derived in the preceding sections with those from Statistics Canada and the Bureau of Labor Statistics. The sixth section will provide concluding remarks.

2.0 Data Overview

The data for this analysis is sourced from Transport Canada's internal Electronic Collection of Air Transportation Statistics (ECATS) program[1]. 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[2].

2.1 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.

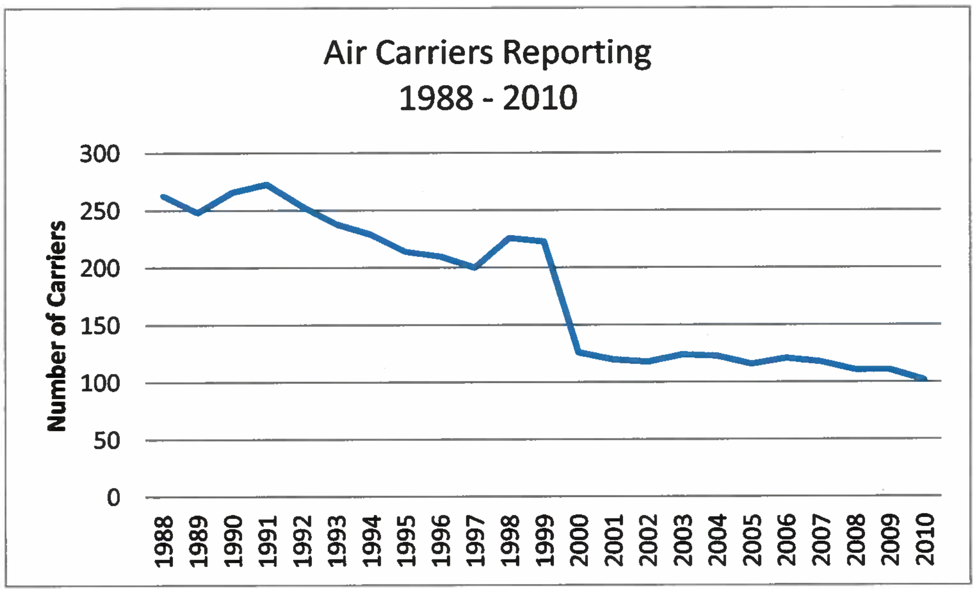

Figure 1: Number of air carriers reporting in survey, 1988 - 2010

As can be seen from Figure 2, 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 ten per cent of total air carrier revenues.

[1] http://www.tc.gc.ca/eng/policy/ecats-national-national-605.htm

[2] http://www23.statcan.gc.ca:81/imdb/p2SV.pl?Function=displayInstrBySubTheme&Item_Id=97413&CE_Id=541&CE_Start=01010001&PItem_Id=97413&PCE_Id=540&PCE_Start=01010001&lang=en&db=imdb&adm=8&dis=2

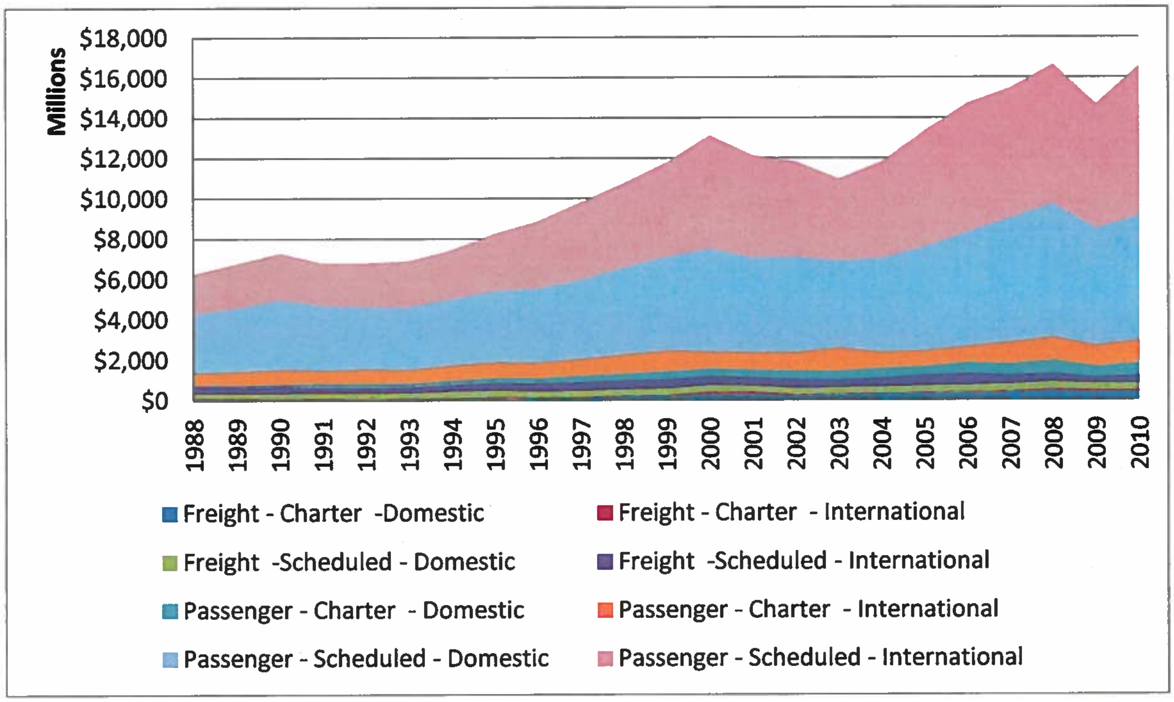

Figure 2: Revenue by Type, Service and Sector 1988 – 2010

3.0 Output Quantity Estimates

3.1 Methodology

Though the main output of the air transport industry is relatively straightforward, i.e. transporting something from one point to another, there are many different characteristics which can be used to differentiate the service. As detailed in the previous section distinction can be made between passenger and freight movements, scheduled and chartered services, and domestic and international routes, to name a few. Below is the complete segmentation of output categories used in this analysis:

- Passenger
  - Scheduled
    - Domestic
    - International
  - Charter
    - Domestic
    - International
- Freight
  - Scheduled
    - Domestic
    - International
  - Charter
    - Domestic
    - International

To produce a 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 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 the revenue per passenger kilometre or tonne-kilometre, depending on which movement type between passenger or freight transport. The yield must be adjusted to take into account the different operating stage lengths of the various carriers. A stage length is the distance flown between an origin and destination. As suggested by Hamlin (2012), due to fixed operating costs per flight i.e. fuel burn for taxi-ing and take-off, contributing a higher proportion of the cost for a shorter stage length the yield charged for those shorter flights would be relatively higher 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:

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

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 routing k,

$\mathrm{Y}_{\mathrm{ighk}}$ is the observed yield for carrier i, movement type g, service h, and routing 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 sum of all of the individual percentage changes is the total change in yields for the year. Each service is also 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:

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

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:

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

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 in a chained index. This can be seen below with the formula:

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

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 next step to estimate the total industry output is to divide the total nominal industry revenues by the computed price index. This will provide a quantity estimate of total industry output.

3.2 Results

The estimation procedure outlined above provided the following results (see Figure 3 below for a plot of the output price index and a trend line derived by linear regression)[3]. Overall output prices increased 26.6 per cent over the 22 year period, or 1.2% per year.

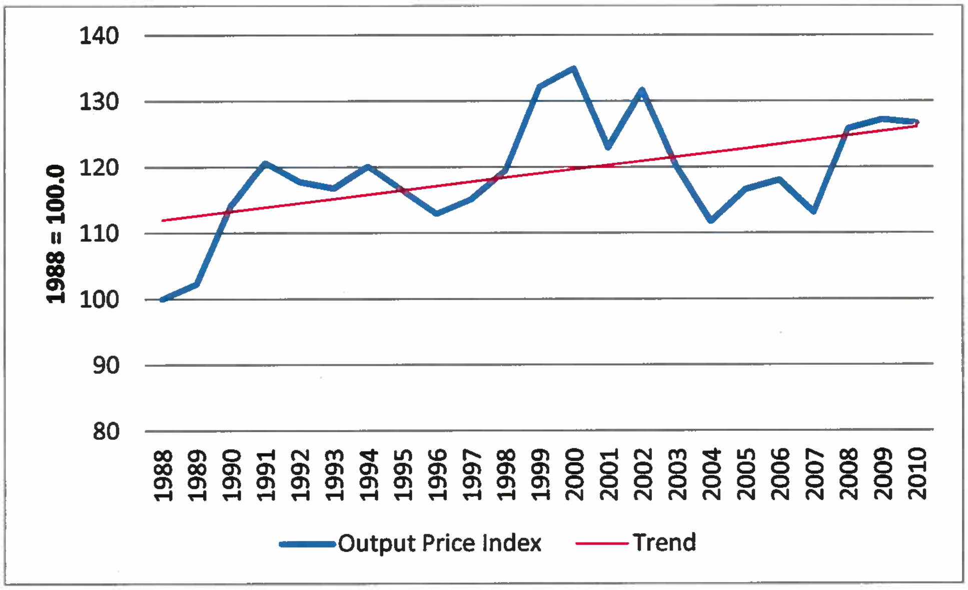

Figure 3: Airline Industry Output Price Index and trend, 1988 – 2010

The above methodology was also used to estimate domestic passenger yields in order to compare the derived index to the data available for average domestic fares from Statistics Canada's Fare Basis survey, accessible from Cansim table 401-0004. Figure 4 below plots the two series for comparison and it can be seen that they seem to exhibit the same annual trends and end the 22 year period with approximately 25 per cent price appreciation.

[3] The regression has an R^2 of 0.2584 and estimates the following equation: y= 0.6388x + 111.3

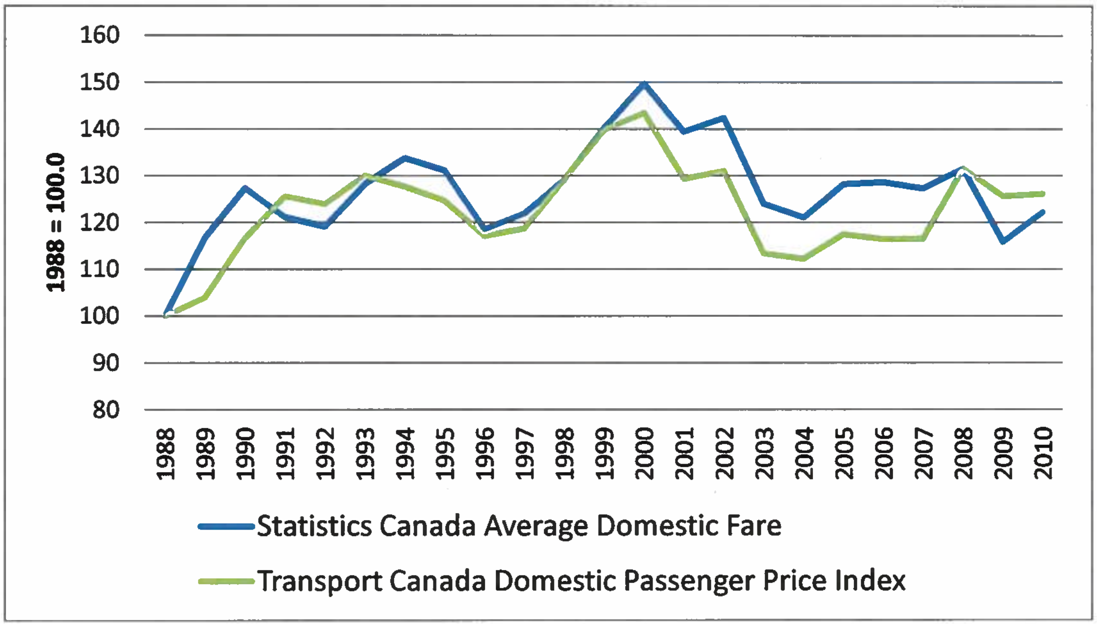

Figure 4: Statistics Canada average domestic fare vs. Transport Canada domestic Price index, 1988 - 2010

With relatively stable (or very moderatly increasing) price variation from year to year, we can see from Figure 5 that any variation in the volume of output of the airline industry would have an almost direct effect on total revenue. Initially from 1988 to 1991 prices rose faster than the decrease in ouput, so revenue also grew. Output then started to increase gradually and because prices remain relatively stable, revenues rose steadily as well. Output suffered after 2001, most likely due in part to the terrorist bombings of 2001, and revenues also decreased due to price reductions. Prices then stabilised around 2004 and output began to increase substantially. The impact of the economic downturn can be seen in 2009 with a sharp reduction in output quantities, followed by a recovery in 2010.

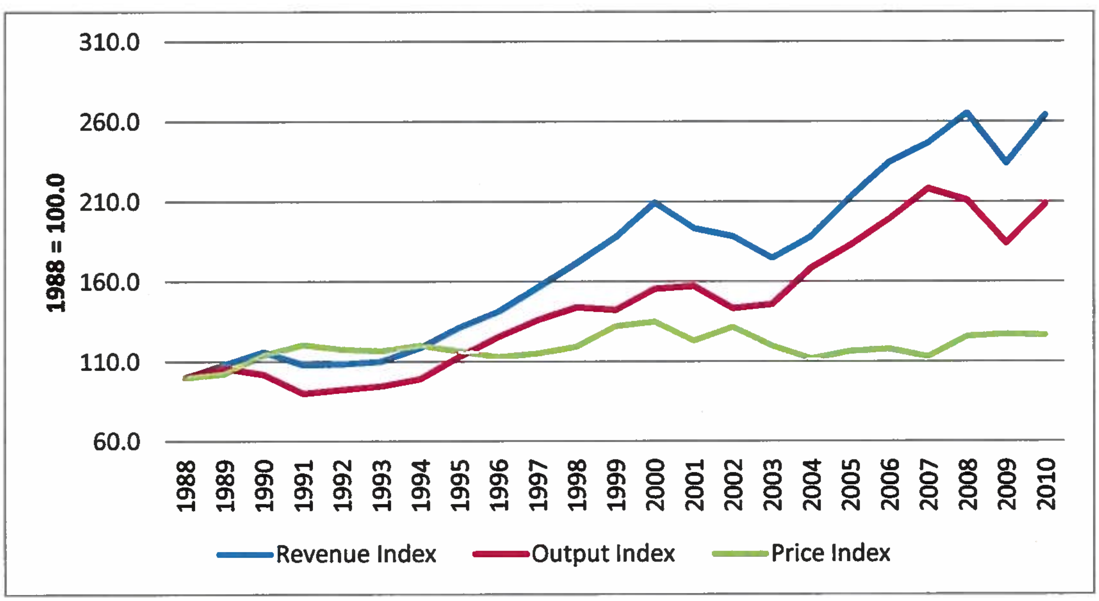

Figure 5: Airline output, revenue and price indices, 1988 - 2010

With revenue, output and price indices estimated the effect of the variation in prices and output on revenues can be examined by looking at the year to year changes in the the three indices (see table 1). For example, in 1989 revenue increased 8% which was comprised of a 6% increase in output and a 2% increases in prices.

Table 2 below presents the average percentage change of the three indices for the 1989-2010 period and various sub-periods. For the 21 year period prices have increased 26.6 per cent, for a compound annual growth rate (CAGR) of 1.1 per cent and a standard deviation of 5.9 per cent. Output has increased 108.6 per cent for a CAGR of 3.4 per cent and a standard deviation of 8.0 per cent while revenues have increased 164.1 per cent for a CAGR of 4.5 per cent and a standard deviation of 7.5 per cent. Prices increased the fastest during the 1990 to 1995 sub-period at an average rate of 2.3 per cent per year, while ouput and revenue increased the fastest during the 1995 to 2000 period at 7.9 and 9.9 per cent, respectively. Prices decreased 3.1 per cent during the 2000 to 2005 period, but due to an increase in output of 3.8 per cent revenues also increased by 0.3 per cent.

Year	Price index	Output index	Revenue index	Price index Y/Y % Change	Output index Y/Y % Change	Revenue index Y/Y % Change
1988	100.0	100.0	100.0			
1989	102.3	105.7	108.2	2.3%	5.7%	8.2%
1990	114.2	101.8	116.2	11.6%	-3.8%	7.4%
1991	120.7	89.7	108.2	5.7%	-11.9%	-6.9%
1992	117.7	92.1	108.5	-2.4%	2.7%	0.2%
1993	116.8	94.2	110.0	-0.8%	2.3%	1.5%
1994	120.1	98.9	118.7	2.8%	4.9%	7.9%
1995	116.5	113.0	131.7	-3.0%	14.3%	10.9%
1996	112.9	125.3	141.5	-3.1%	10.9%	7.5%
1997	115.1	135.9	156.5	2.0%	8.5%	10.6%
1998	119.4	143.8	171.6	3.7%	5.8%	9.7%
1999	132.1	142.2	187.9	10.6%	-1.1%	9.5%
2000	134.9	155.4	209.6	2.1%	9.2%	11.5%
2001	123.0	157.2	193.3	-8.8%	1.1%	-7.8%
2002	131.7	143.2	188.5	7.1%	-8.9%	-2.5%
2003	120.0	145.8	174.9	-8.9%	1.8%	-7.2%
2004	111.8	168.4	188.2	-6.9%	15.6%	7.6%
2005	116.6	182.6	212.9	4.3%	8.4%	13.1%
2006	118.0	199.0	234.8	1.2%	9.0%	10.3%
2007	113.1	218.1	246.7	-4.1%	9.6%	5.1%
2008	125.8	211.0	265.4	11.2%	-3.3%	7.5%
2009	127.2	184.1	234.1	1.1%	-12.7%	-11.8%
2010	126.6	208.6	264.1	-0.4%	13.3%	12.8%

Table 1 Price, Output and Revenue Indices, 1988-2010

Period	Price Index	Output Index	Revenue Index
1989 - 2010	1.2%	3.7%	4.8%
1990-1995	2.3%	1.4%	3.5%
1995-2000	2.1%	7.9%	9.9%
2000-2005	-3.1%	3.8%	0.3%
2005-2010	2.2%	4.0%	6.2%

Table 2: Average percentage change for various sub periods

4.0 Inputs

4.1 Overview

This analysis uses four major input categories to estimate the productivity of the airline industry. The categories are Labour, Energy, Capital (comprised 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 partial productivity measure divides the total output quantity by the total input quantity, thus it is a ratio of the two quantities. From the Bureau of Labor Statistics (2012) this measure can be represented using the following formula:

$$Input\ Index = \frac{\frac{Q_t}{Q_0}}{\frac{Input_t}{Input_0}}$$

Where,

Q is the output quantity,

Input is the input quantity of a specific factor of production, such as labour,

t is the current year,

0 is the base year.

For example, dividing the total Gross Domestic Product of an economy by the total labour hours worked in that economy provides a measure of labour productivity. 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.

To gain an understanding of the input structure of the airline industry Figure 6 below portrays the composition of the share of each input in total input costs from 1988 to 2010. As in Duke and Torres (2005), the Intermediate cost share is the largest component, on average comprising almost 50% of the total operating costs of the industry. Wages made up the second largest category of input costs with an average of 22.2 per cent and fuel the third category at 17.5 per cent. Since 2003 increasing fuel prices have caused fuel to become a larger proportion of costs, averaging 23.1 per cent in the last 7 years and hitting 30.8 per cent in 2008. Capital costs made up 14.9 per cent of total costs.

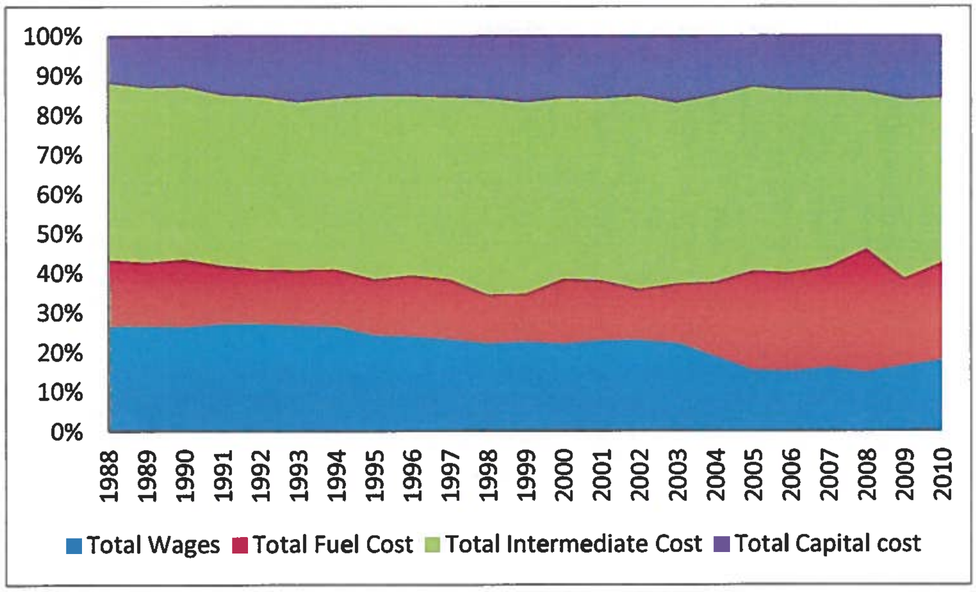

Figure 6: Input costs proportion of total operating costs, 1988-2010

4.2 Detailed Results

The next section of the analysis will detail each of the four inputs used as factors of production and outline the methodology used to estimate their quantities.

4.3 Labour

As outlined previously, wages were the second largest input used by airlines. There were approxiametly 50,000 employees in the industry in 1988 and roughly the same number in 2010. Figure 7 portrays the variability of employment in the industry, especially a large contraction beginning in 2001. This was largely due to the outsourcing of aircraft servicing personnel by one of the large carriers.

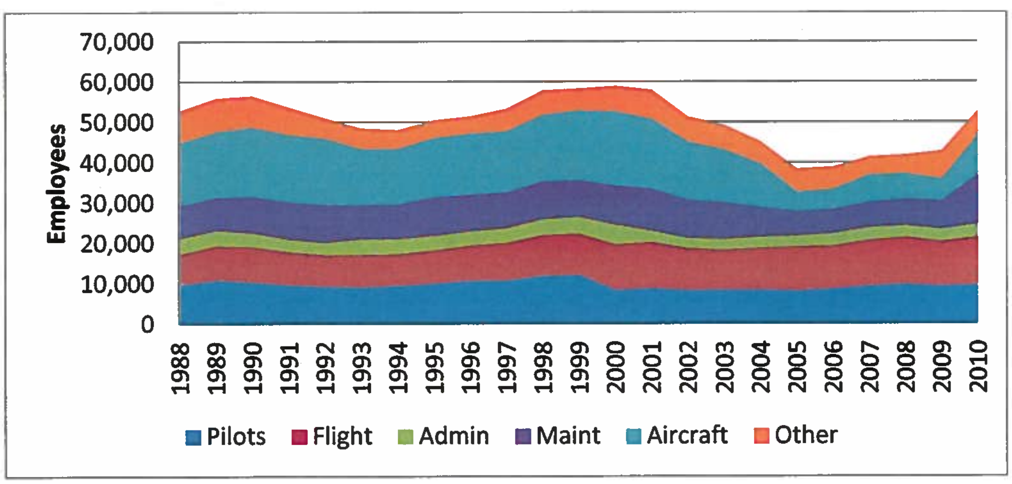

Figure 7: Composition of Labour, 1988-2010

4.3.1 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 the translog multilateral index procedure. The weighting and aggregation formula can be seen below:

$$L_T = \sum_i [S_i * (LN(E_i)^T - LN(E_i)^{T-1})]$$

Where,

L_T is the sum of the weighted quantity changes,

T is the time period,

E_i is the amount of employees in labour category i,

S_i is the share of labour costs for employees in labour category i, which is determined by:

$$S_i = \frac{1}{2} * \left[\left(\frac{LC_i^T}{\sum_i LC_i^T}\right) + \left(\frac{LC_i^{T-1}}{\sum_i CC_i^{T-1}}\right)\right]$$

Where,

LC_i^T is the share of total labour costs for employee category i,

T is the time period.

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. Shifts in employment to higher salaried occupations within the industry show up as providing more labour input.

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. This can be seen below with the formula:

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

Where,

I_T is the labour quantity index for time T,

L_T is the sum of the weighted natural logs of the employee quantity changes.

4.3.2 Labour Estimation Results

When aggregated into the index labour utilization is relatively stable from 1988 to 2001 after which it begins to decline. Labour utilization hits a trough in 2005 and this was the time when output was rising dramatically for the Canadian airline industry. Thus, with decreasing labour use and increasing output the labour productivity of the industry grew rapidly. See Figure 8 below for a graph of the labour use, output, and labour productivity indices.

Labour productivity has grown 111.1 per cent from 1988 to 2010, for a compound annual growth rate of 3.5 per cent and a standard deviation in the growth rates of 9.2 per cent. The fastest period of growth for labour productivity was from 2000 to 2005 at 9.4 per cent, while the slowest growth period was from 2005 to 2010 at 1.7 per cent.

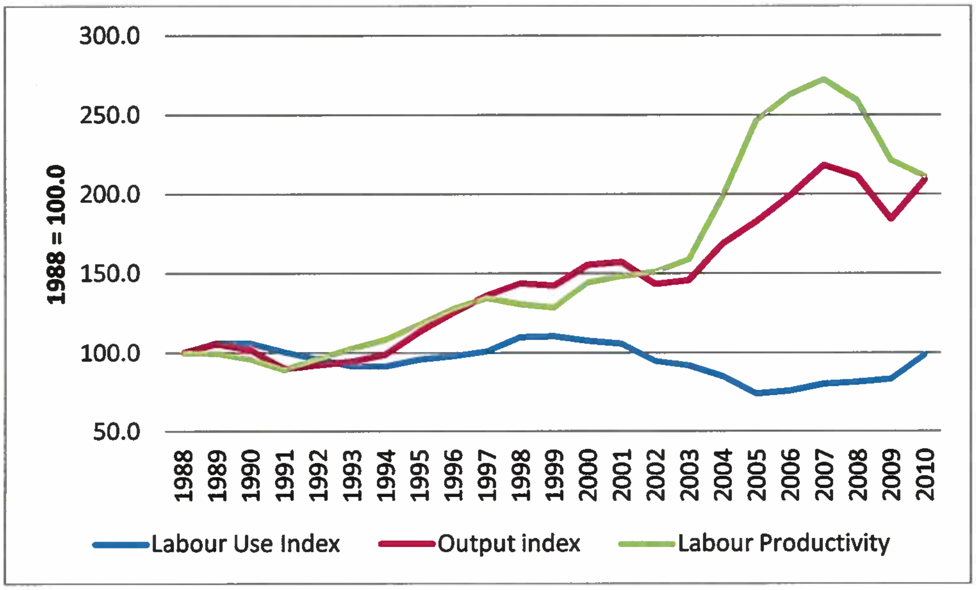

Figure 8: Output, labour use and labour productivity, 1988 – 2010

4.4 Energy

4.4.1 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 which is indexed to the amount used in 1988 and this level is set to 100.0.

4.4.2 Energy Estimation Results

As expected, energy use exhibits a similar trend to output growth. With increased travel demand, more energy will be required. One of the interesting points about the energy use index is that it is not rising as fast as the output growth and the gap seems to be widening. This implies that air carriers are utilizing modern and more fuel efficient aircraft. The rising fuel prices of the late 2000's probably provided the incentive for many air carriers to implement energy saving initiatives. See Figure 9 below for a graph of the energy use, output index and energy productivity indices.

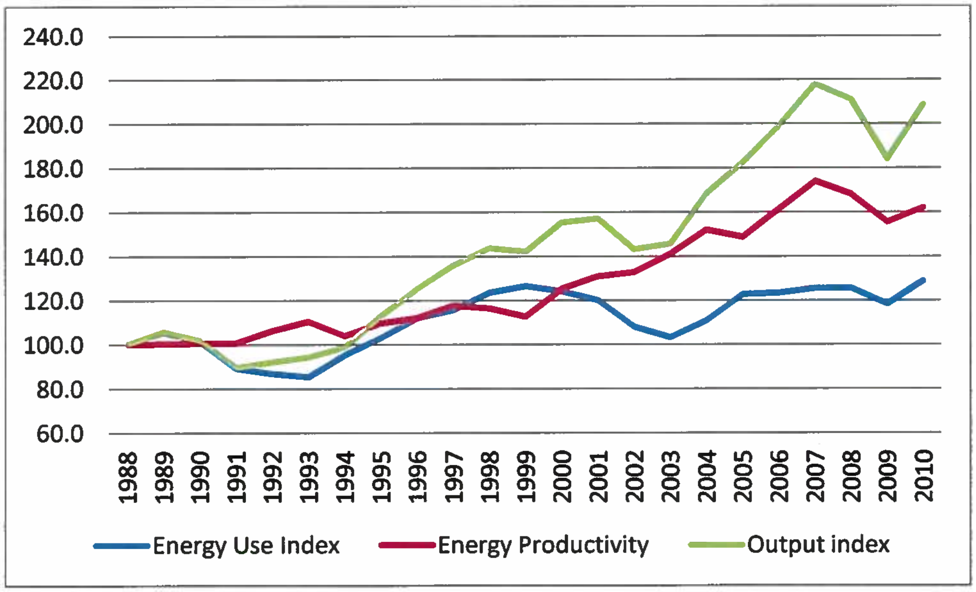

Figure 9 Output, Energy use and Energy Productivity, 1988 - 2010

4.5 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.

4.6 Owned Capital

4.6.1 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:

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

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. From 1972-1987 the average land to total asset ratio for the Airline industry from Statistics Canada (Cansim Table 180-0002) was 0.00327.

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 difference 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 into land then 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. The land price index is obtained from the land component of the New Housing Price Index, Statistics Canada Table 327-0046.

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 the capital in the airline industry. The variation in the ratio is used as a measure of the variation in capital prices. 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 depreciation quantities.

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 (a value of 1.12) 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[4].

The productivity of capital is sensitive to this initial value. As can be seen in Figure 10 higher values of intial capital stock lead to lower growth rates in capital use. Given a specific level of output, the lower growth rates in capital stock translate to a higher growth rate in capital productivity. Figure 10 presents the effect on compound annual growth rates for capital use and capital productivity when varying stock to book value ratios are used for the initial capital stock in 1988.

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[4] From capital stock data provided by Statistics Canada Capital Stock division.

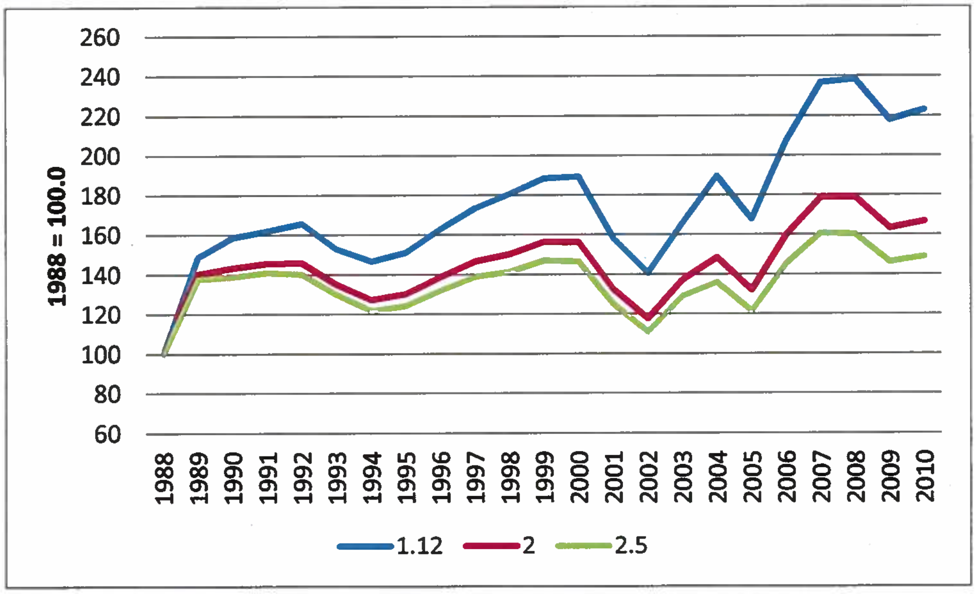

Figure 10: Capital use estimates with varying levels of initial stock to book value

Stock to Book Value ratio	Capital Use	Capital Productivity
1.12	3.7%	-0.3%
2	2.3%	1.0%
2.5	1.8%	1.5%

Table 3: Compound growth rates, 1988 to 2010

4.7 Leased Capital

4.7.1 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.

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 the aircraft the ratio of current and constant dollar value estimates of that asset class are used[5]. An exchange rate adjustment is also applied to the aircraft price index.

[5] From capital stock data provided by Statistics Canada Capital Stock division.

To estimate the cost of leasing the aircraft the 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:

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

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 Statistics Canada data from the Capital Stock division.

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.

4.7.2 Results

Capital use increased 123.1 per cent from 1988 to 2010, for a compound annual growth rate of 3.7 per cent and a standard deviation of 14.0 per cent. Capital use increased substantially from 1988 to 1992 (59.8 per cent), decreased from 1992 to 1994 (11.9 per cent) and then increased steadily up to 2000 (26.2 per cent). 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 per cent but the standard deviation was 15.1 per cent. See Figure 11 below for a graph of output, capital use and capital productivity.

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 per cent from 1988 to 2010 for a CAGR of -0.3 per cent and a standard deviation of 12.0 per cent. The strongest growth in capital productivity was seen from 2000 to

2005 with an average growth rate of 3.9 per cent. The weakest growth period was from 1990 to 1995 with an average growth rate of 1.4 per cent.

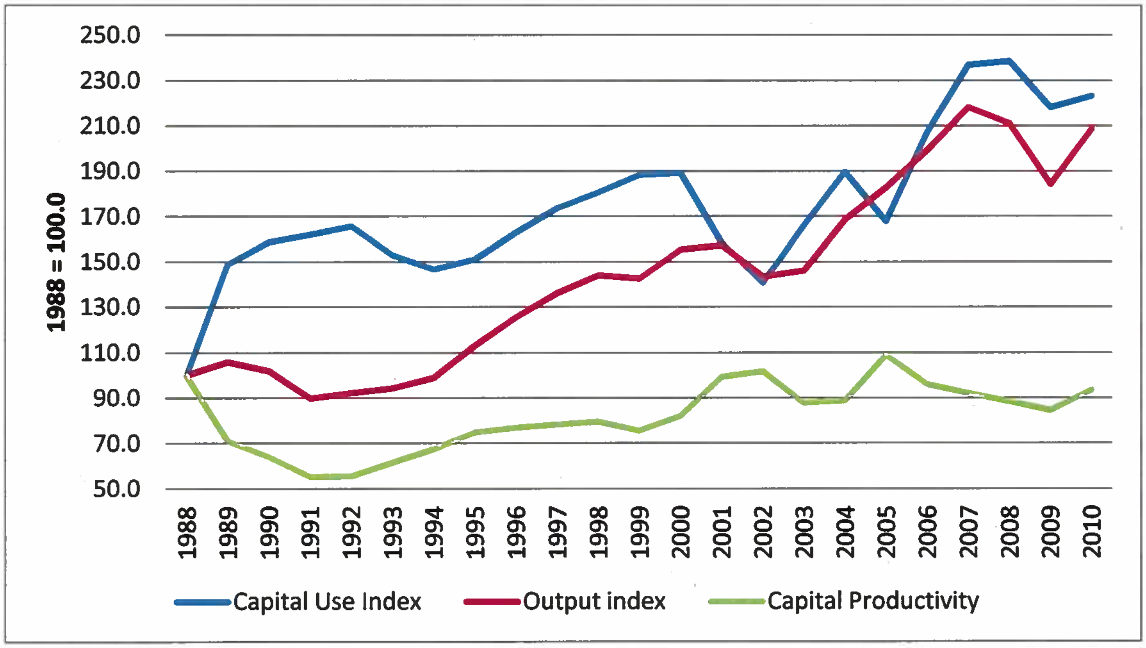

Figure 11: Output, Capital use and Capital productivity, 1988 - 2010

4.8 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. The figure below shows that the "other" category of Intermediate expense makes up roughly 54% of the input.

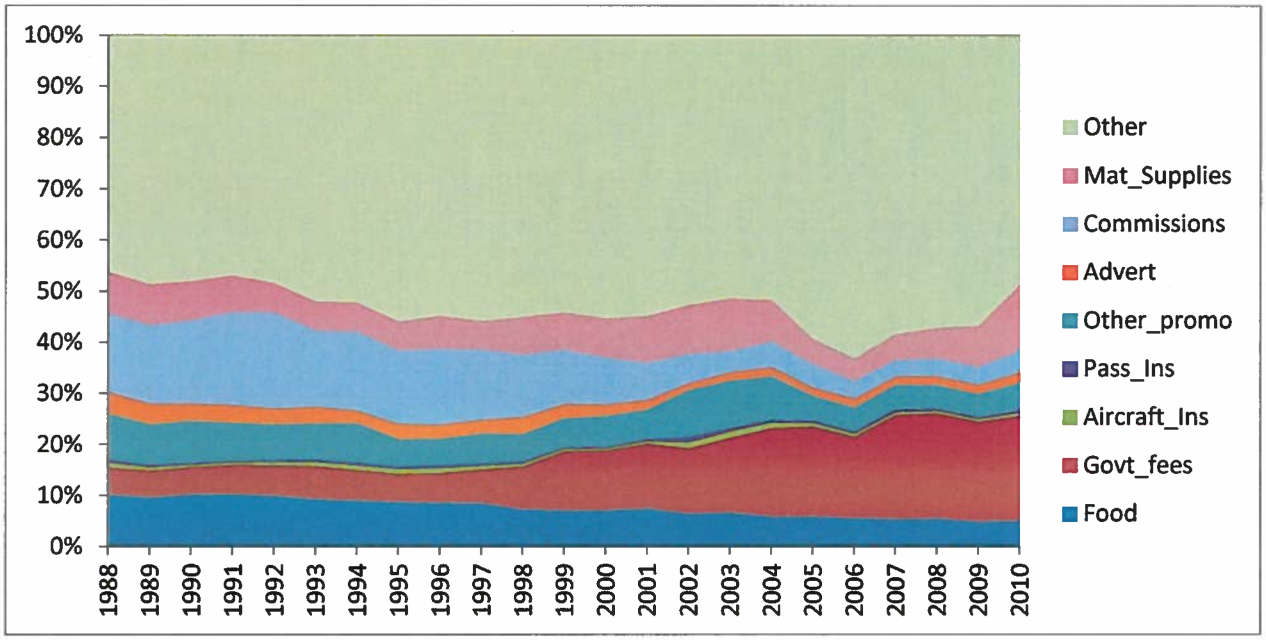

Figure 12: Composition of Intermediate inputs, 1988 - 2010

4.8.1 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 variation in 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[6]. 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.

[6] Informetrica Limited.

4.8.2 Estimation Results

From 1988 to 1995 Intermediate input quantities are quite stable. From 1995 they gradually increase, as do output quantities. Around 2003 the quantity of other inputs stabilizes and does not vary much, while output starts to increase rapidly. This causes the productivity of other inputs to increase and tracks output growth very closely. See Figure 13 for the Intermediate quantity, Output quantity and Intermediate productivity indices.

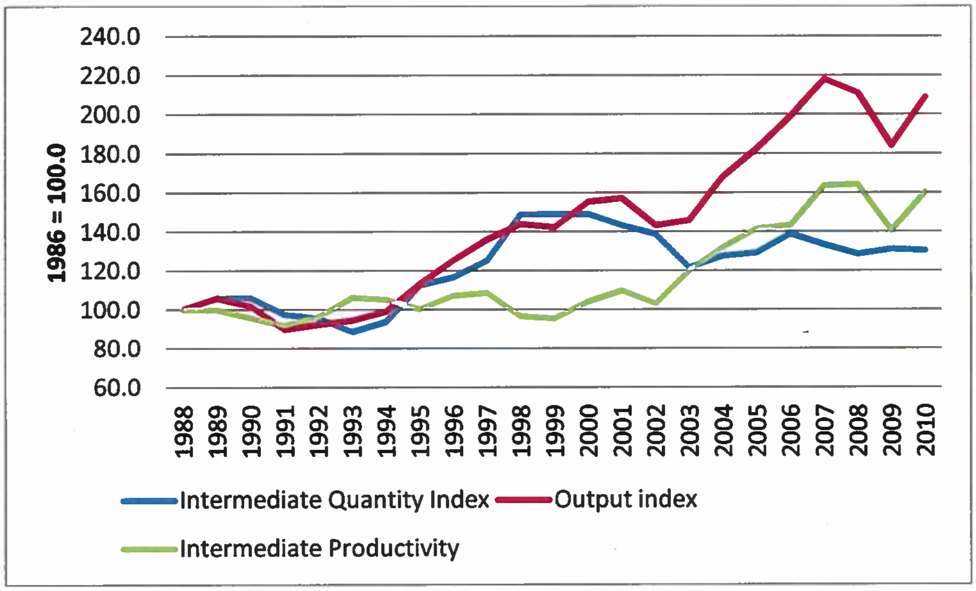

Figure 13: Output, Intermediate quantity use and productivity, 1988 - 2010

4.9 Total Factor Inputs

4.9.1 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. This is the same methodology for combining inputs as was used in the labour quantity estimation. The updated formulae to derive the Total Factor Input quantity can be seen below:

$$TFI_T = \sum_i [S_i * (LN(IN_i)^T - LN(IN_i)^{T-1})]$$

Where,

TFI_T is the sum of the weighted quantity of input changes,

T is the time period,

IN_i is the quantity of amount for input category i,

S_i is the share of total input costs for input category i, which is determined by:

$$S_i = \frac{1}{2} * \left[\left(\frac{\mathrm{IC}_i^T}{\sum_i \mathrm{IC}_i^T}\right) + \left(\frac{\mathrm{IC}_i^{T-1}}{\sum_i \mathrm{IC}_i^{T-1}}\right)\right]$$

Where,

IC_i^T is the share of input costs for input category i,

T is the time period.

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 costs expense for the year. All of the input expenses are extracted from the air carriers' income statement. These would be the total amount of wages paid, the total spent on fuel, the cost of capital and the other operating expenses not already aggregated into the previous expenditures. The cost of capital for owned capital is determined as the amount paid on debt interest and the amount paid for depreciation, while the cost of capital for leased capital is the amount paid for aircraft rentals.

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. This can be seen from the formula:

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

Where,

I_T is the total factor input index for time T,

L_T is the sum of the weighted natural logs of the input quantity changes.

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, as was done previously to estimate partial productivity measures. The results are shown below (see figures 14 and 15).

4.9.2 Results

The total factor productivity of the airline industry increased 160.4 per cent from 1988 to 2010, for a compound annual growth rate of 2.2 per cent and a standard deviation in the growth rates of 6.2 per cent. The period with the highest average growth rate was from 2000 to 2005 with a growth rate of 6.6 per cent and the lowest growth rate was 1.3 per cent from 1990 to 1995. See Figure 14 for the annual growth rates for Total Factor Productivity as well as a three-year moving average plot.

The weighted index of all inputs use tracks the output quantity index until roughly 1999 when output starts to increase faster than the input use. From 2003 to 2007 output quantities grow much faster than inputs, as input use seems to stabilize. See Figure 15 for the aggregate input, output and total factor productivity indices.

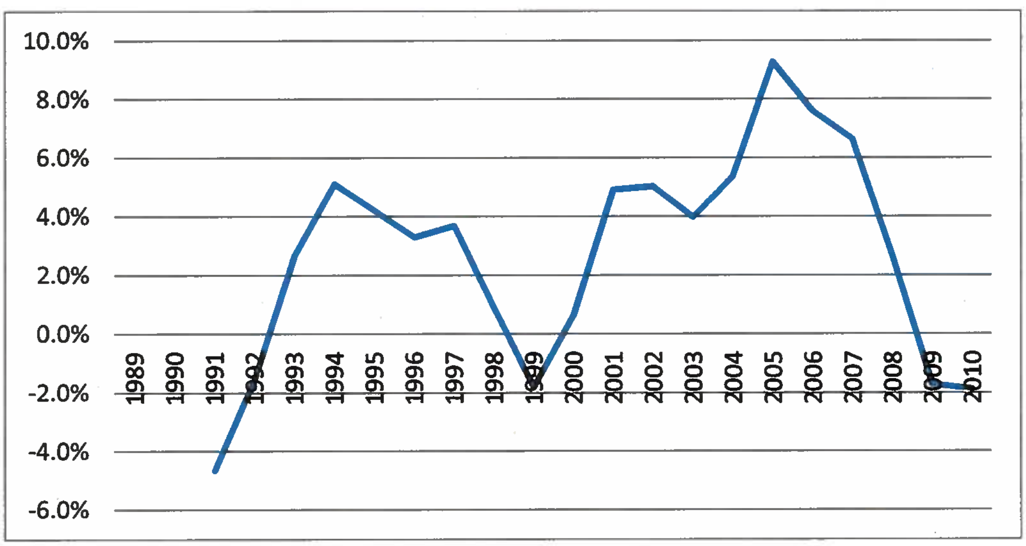

Figure 14 Total Factor Productivity growth rate, 3 year moving average, 1989 - 2010

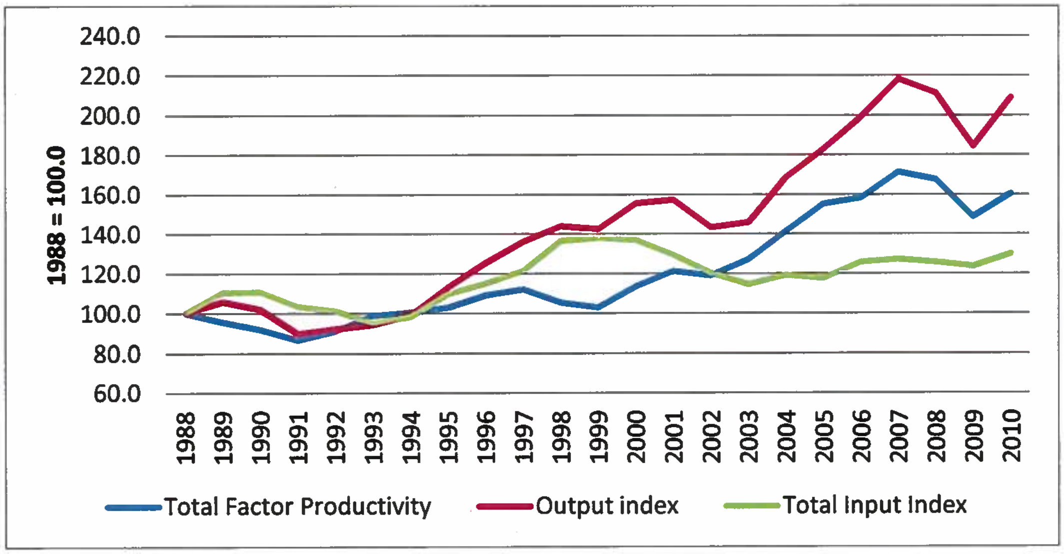

Figure 15 Output, total inputs and Total Factor Productivity, 1988 - 2010

5.0 Comparison with Other Estimates

5.1 Statistics Canada

Statistics Canada administers a productivity program that utilizes the national accounts industry classification system (NAICS) segmentation of economic activity. This section of the analysis compares the estimates derived using the methodology from the preceding sections with the estimates published by Statistics Canada in the Cansim database. Statistics Canada labels their total factor estimates as multifactor estimates.

5.1.1 Overview

Due to confidentiality concerns Statistics Canada publishes data for the transportation industry as an aggregate of four sub-categories NAICS 481 (Air), 482 (Rail), 483 (Marine) and 487 (Scenic and Sightseeing). Thus, Statistics Canada's aggregates air transport, rail, inland water and sightseeing transportation industries into their publicly available productivity estimates. The most recent estimates are for the year 2008.

As part of the multifactor productivity estimation Statistics Canada uses 6 inputs. They are services, materials, energy, intermediate, capital and labour. Figure 16 details their respective shares over the 1988 to 2008 time period.

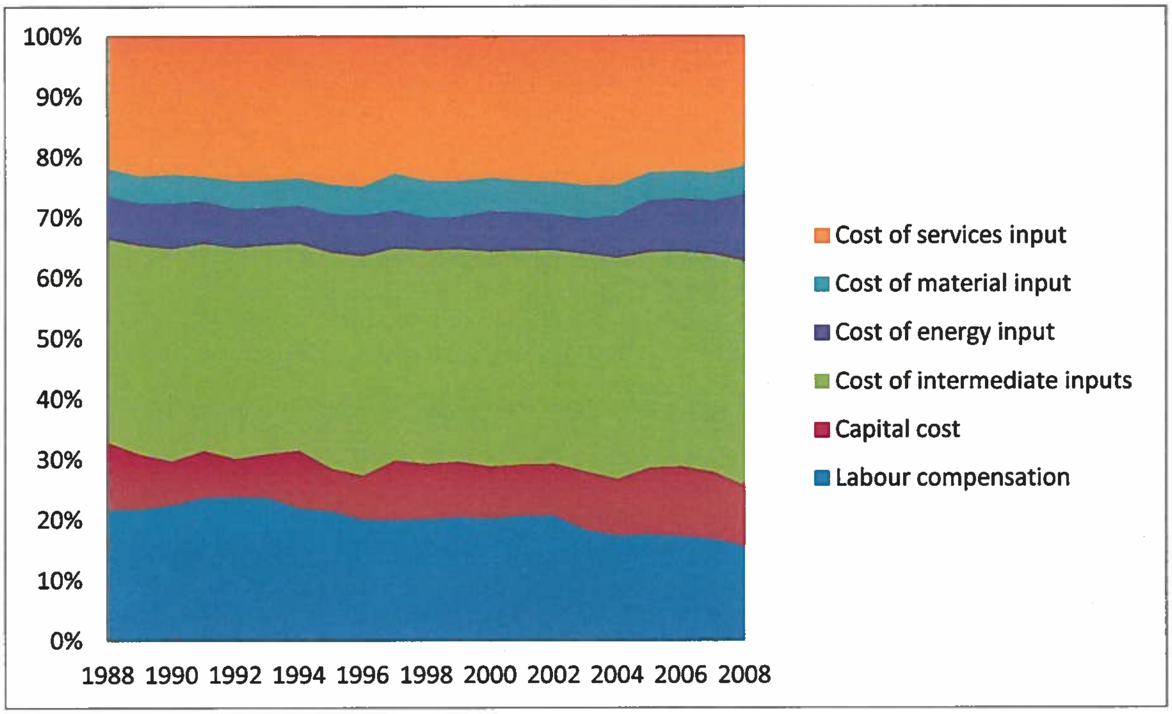

Figure 16: Composition of input shares for Statistics Canada data, 1988-2008

5.1.2 Output

An index is derived from the real gross-output estimate for the Statistics Canada data and is compared with the Transport Canada Air Carrier output index. The Transport Canada index exhibits higher growth rates than the Statistics Canada index and is more volatile. The Transport Canada index has a compound annual growth rate of 3.8 per cent and a standard deviation of 7.2 per cent, compared with 2.1 per cent and 3.8 per cent, respectively, for the Statistics Canada index.

The difference in the growth rates could be due to the fact that the Statistics Canada data is an aggregate of several industries. The industries other than air could be putting downward pressure on the overall index. Further research would be useful in determining the composition of the other industries in the Statistics Canada data.

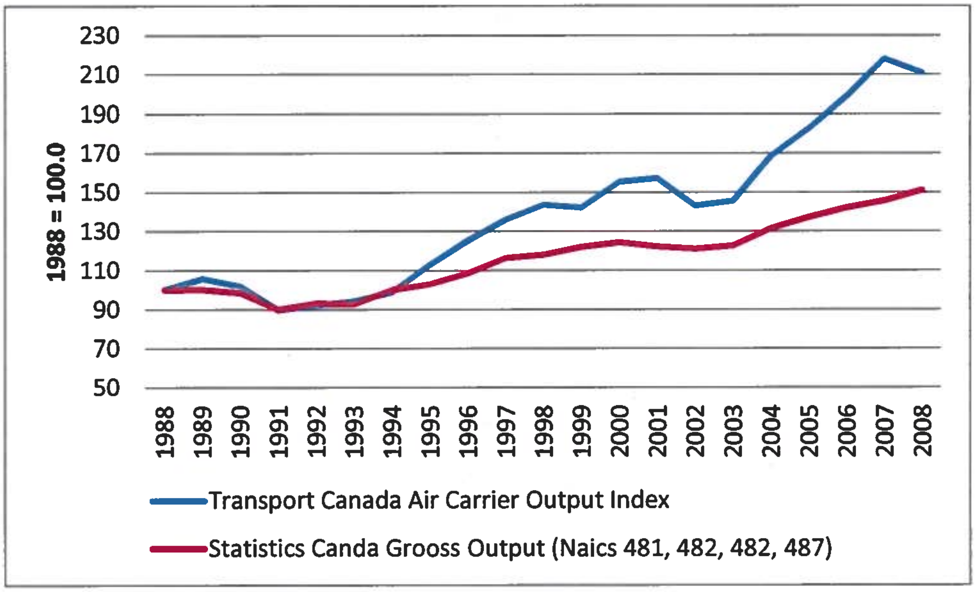

Figure 17: Transport Canada vs Statistics Canada Output Indices, 1988 - 2008

5.1.3 Inputs

Comparing the two total factor input indices shows that the Transport Canada index contains more variability than the Statistics Canada aggregate input index, see Figure 18 for a plot of the indices and Figure 19 for the annual percentage change of the two. The compound annual growth rate for the Statistics Canada total factor index was 2.2 per cent with a standard deviation of 2.6 per cent. The Transport Canada all factor index had a compound annual growth rate of 1.2 per cent and a standard deviation of 6.0 per cent.

Again the variability and growth rate differences between the two estimates may be due to the fact that the Statistics Canada index contains several industries, rather than just the air industry.

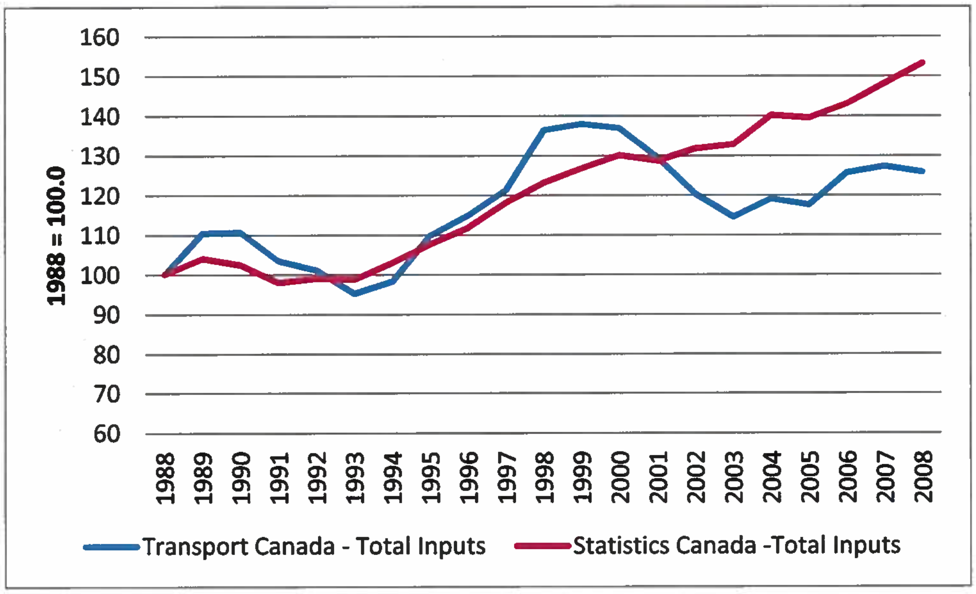

Figure 18: Transport Canda vs. Statistics Canada Total Factor Inputs, 1988 - 2008

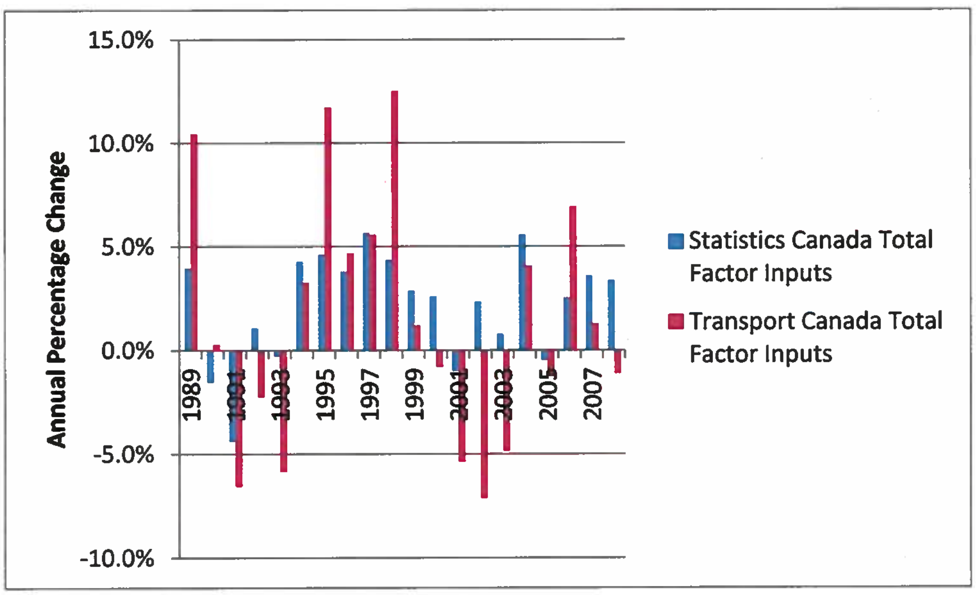

Figure 19: Total factor annual percentage change, 1989-2008

5.1.4 Total Factor Productivity

As explained in the previous sections, dividing total output by total factor input indices provides an estimate of the total factor productivity of the industry. As can be seen from Figure 20, the total factor productivity estimates from the Transport Canada methodology far exceed the estimates from Statistics Canada. From 1988 to 2008 the Transport Canada estimate had a compound annual growth rate of 2.6 per cent and a standard deviation of 5.6 per cent. The Statistics Canada estimate for multifactor productivity actually ended the 20 year period below the level where it started in 1988. Their estimate had a compound annual growth rate of -0.1 per cent and a standard deviation of 2.3 per cent.

This implies that the transport industry has not increased the efficiency of which it uses its inputs at all, and has actually declined in efficiency.

Other than the industry aggregation issue already outlined as a potential difference between the two estimates, Coulombe (2000) also points out two major methodological concerns regarding the capital estimation of the Statistics Canada multifactor productivity program. He points out that by excluding the slow growing components of land and inventories from the definition of capital, the residual components cause that factor to grow too fast.

Conversely, Coulombe (2000) also finds that the form of depreciation used by Statistics Canada causes the capital stock growth rates to be underestimated and this second problem outweighs the first problem. He concludes that Statistics Canada overestimates the growth in multifactor productivity by almost 0.25 per cent per year. These findings cast doubt on the Statistics Canada methodology, though they do point in favour of decreased growth in the multifactor productivity estimate rather than an increase in growth.

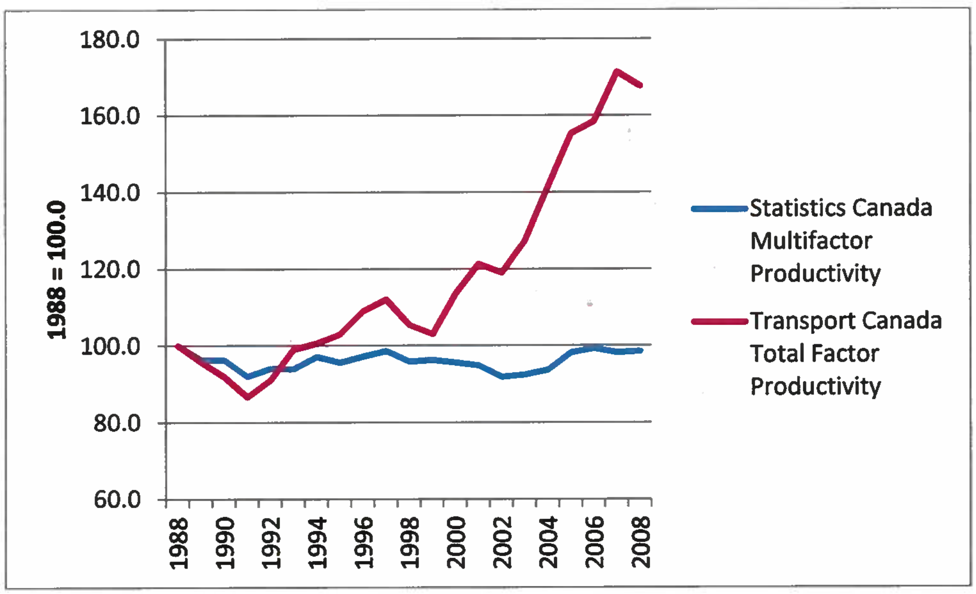

Figure 20

From the preceeding analysis it is quite apparent that a more detailed segmentation of the airline industry from the Statistics Canda data is required to draw any conclusions about the difference in methodologies.

5.2 Bureau of Labour Statistics

The United States Bureau of Labor Statistics (BLS) publishes multi-factor productivity estimates for the transportation sector in the United States at a more detailed level than Statistics Canada. Estimates are available for the air sector (NAICS 481) and cover the 1987 to 2010 period. This section of the analysis compares the growth rates in output, inputs and total factor productivity between American estimates from the BLS and the estimates for the Canadian airline industry from the methodology outlined above.

5.2.1 Output

The output growth rates between the two countries airline sectors exhibit similar trends, with the Canadian industry displaying more variability, see Figure 21 below. From 1988 to 2010 the output of the Canadian airline industry increased 108.6 percent, for a compound annual growth rate of 3.4 per cent and a standard deviation of 8.0 per cent. The American airline industry grew 77.5 per cent in that time period, for a compound annual growth rate of 2.6 per cent and a standard deviation of 4.4 per cent. Both industries seem to have been affected by a drop in output in the early 2000's as well as in 2009. The output of the Canadian airline industry experienced slower growth from 1990 to 1994 and faster growth from 2005 to 2008.

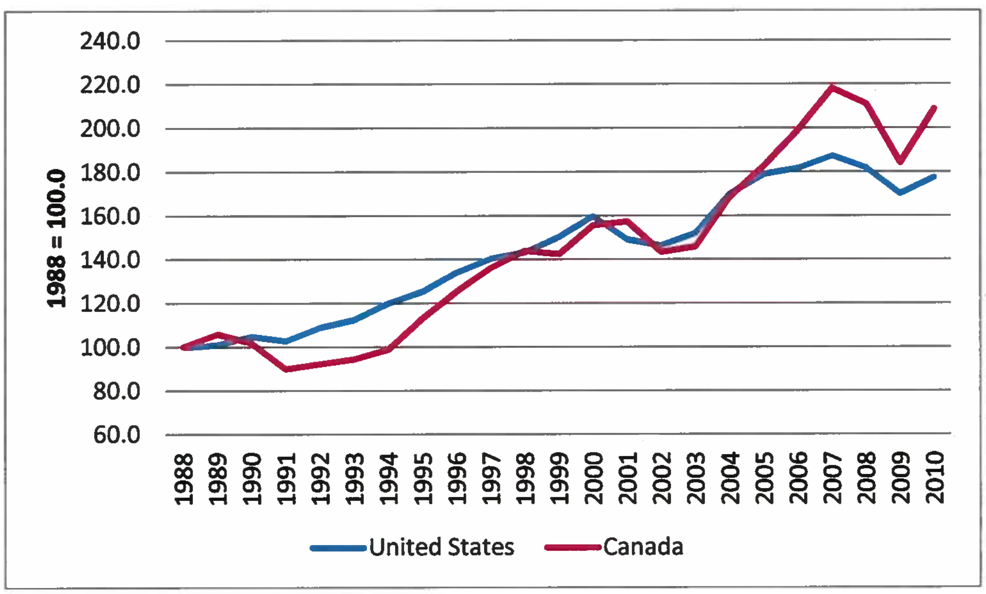

Figure 21: Output Indices, 1988 – 2010

5.2.2 Inputs

The American industry ended the period in 2010 at an input quantity use below the level it was at in 1988, decreasing 5.9 per cent for a compound annual growth rate of -0.3 per cent and a standard deviation of 4.9 per cent. The Canadian airline industry input use grew 30.1 per cent during that period for a compound annual growth rate of 1.2 per cent and a standard deviation of 5.8 per cent. From 1994 to 2003 both the Canadian and American airline industries exhibit a hump shaped total input use index, see Figure 22.

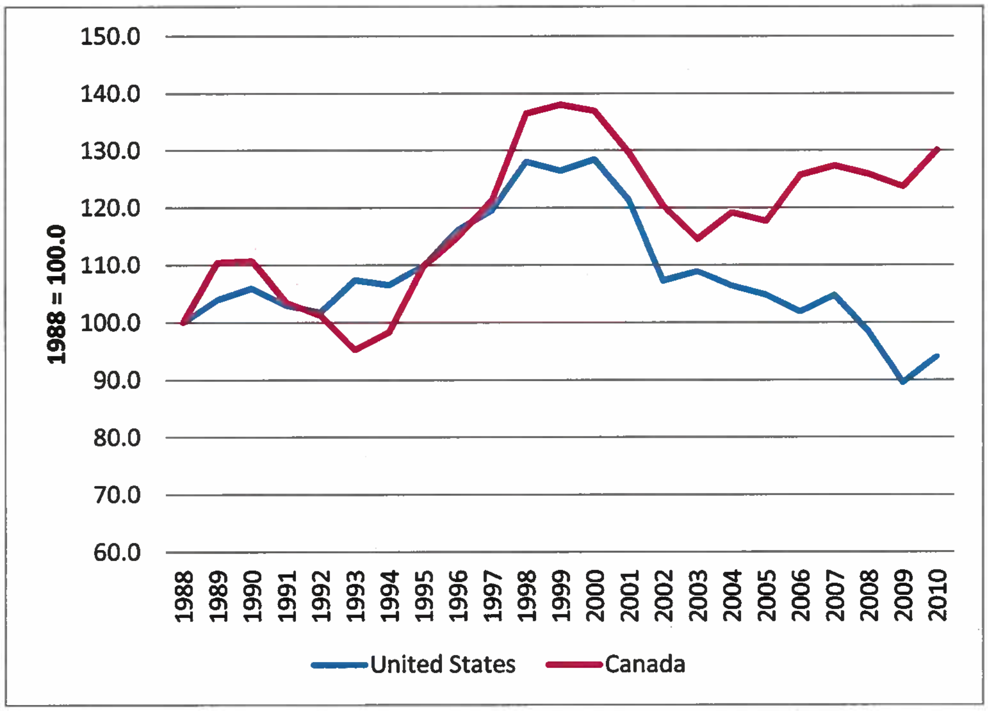

Figure 22: Input Indices, 1988 – 2010

5.2.3 Total Factor Productivity

With similar trends in outputs and inputs, it is not a surprise to see that the total factor productivity indices of the two sectors also exhibit similar trends. The American airline industry had a faster productivity growth rate through the period, due to the relative efficiency of their input use. Their total factor productivity grew 88.7 per cent for a compound annual growth rate of 2.9 per cent and a standard deviation of 4.6 per cent. The Canadian airline industry total factor productivity grew 60.4 per cent for a compound annual growth rate of 2.2 per cent and a standard deviation of 6.2 per cent. See Figure 23 below.

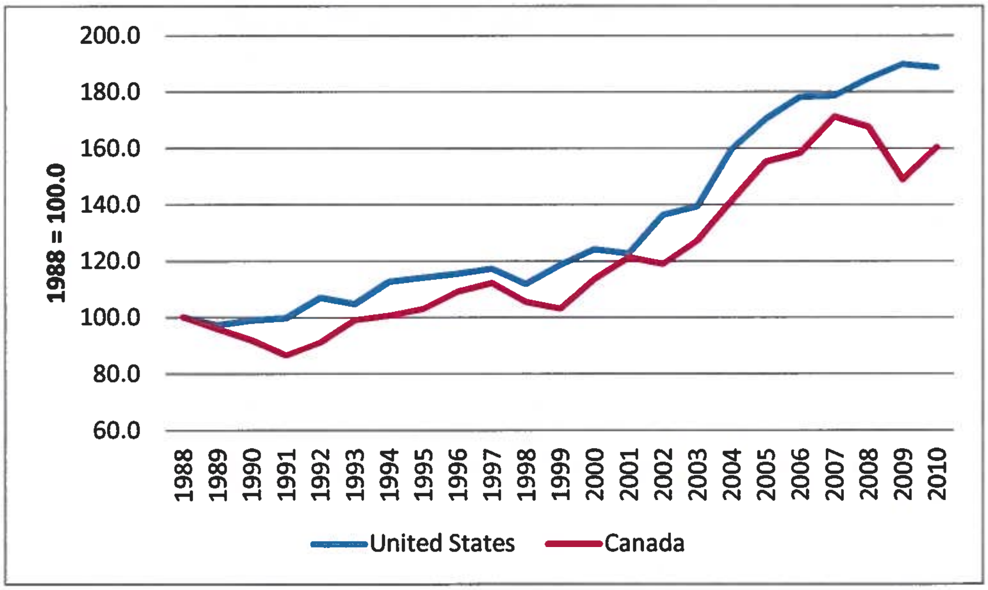

Figure 23: Total Factor Productivity Indices, 1988-2010

Thus, from the preceding analysis it can be seen that both the American and Canadian airline sectors exhibit similar trends in output, inputs and total factor productivity over the 22 year period, with the American industry performing slightly better in terms of efficiency of using inputs to create outputs.

6.0 Conclusion

This analysis of the Canadian airline industry has estimated output prices and quantities for the 1988 to 2010 period. Output quantities have grown at a much faster pace than 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 and the estimation of the initial stock of capital has an impact on the growth rates in productivity. Intermediate inputs are a major share of total inputs and their productivity has increased. The total factor productivity of the sector has increased at a much faster rate than the inputs used to produce them.

Comparisons with official estimates from other agencies show that more detailed data than what is publically available from Statistics Canada is necessary in order to compare methodologies. The Transport Canada methodology shows a very high rate of growth in total factor productivity when compared to Statistics Canada's aggregate industry estimate. At a more granular data level the comparison between Canadian and American airline sectors showed very similar rates of growth for output, input and total factor productivity, with the American sector showing slightly higher efficiency rates.

Appendix Tables

Year	Output index	Total Input Index	Energy Use Index	Labour Use Index	Intermediate Quantity Index	Capital Use Index	Labour Productivity	Energy Productivity	Capital Productivity	Intermediate Productivity	Total Factor Productivity
1988	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1989	105.7	110.4	105.5	106.1	105.9	148.8	99.7	100.2	71.1	99.9	95.7
1990	101.8	110.7	101.3	106.0	106.2	158.7	96.0	100.5	64.1	95.9	91.9
1991	89.7	103.5	89.2	100.7	97.6	161.9	89.0	100.6	55.4	91.9	86.7
1992	92.1	101.1	86.8	95.8	95.6	165.7	96.2	106.1	55.6	96.3	91.1
1993	94.2	95.2	85.4	91.5	88.7	152.9	103.0	110.4	61.6	106.3	99.0
1994	98.9	98.3	95.3	91.2	93.8	146.6	108.4	103.8	67.4	105.4	100.6
1995	113.0	109.8	103.1	95.8	112.6	151.1	118.0	109.6	74.8	100.4	102.9
1996	125.3	114.9	111.9	98.0	116.7	162.9	127.9	112.0	76.9	107.3	109.1
1997	135.9	121.3	115.6	101.0	125.2	173.5	134.5	117.6	78.3	108.6	112.1
1998	143.8	136.4	123.5	109.9	148.9	180.6	130.8	116.4	79.6	96.5	105.4
1999	142.2	138.0	126.5	110.6	149.1	188.4	128.7	112.5	75.5	95.4	103.0
2000	155.4	136.9	124.1	107.7	149.0	189.2	144.3	125.2	82.1	104.2	113.5
2001	157.2	129.6	120.2	106.0	143.2	158.3	148.3	130.8	99.3	109.8	121.3
2002	143.2	120.3	108.0	94.8	138.7	140.6	151.1	132.6	101.8	103.2	119.0
2003	145.8	114.5	103.2	91.8	121.5	165.9	158.8	141.2	87.9	119.9	127.3
2004	168.4	119.1	110.8	84.9	127.6	189.6	198.4	152.0	88.8	132.0	141.4
2005	182.6	117.6	122.7	74.1	129.1	167.8	246.5	148.8	108.8	141.4	155.2
2006	199.0	125.7	123.3	75.8	138.9	207.2	262.6	161.4	96.1	143.3	158.3
2007	218.1	127.3	125.4	80.1	133.3	236.7	272.3	173.9	92.1	163.5	171.3
2008	211.0	125.9	125.6	81.4	128.6	238.5	259.1	168.0	88.4	164.0	167.6
2009	184.1	123.7	118.5	83.2	131.0	218.1	221.4	155.4	84.4	140.5	148.9
2010	208.6	130.1	128.7	98.8	130.3	223.1	211.1	162.1	93.5	160.1	160.4

Table 4: Transport Canada Canadian Airline Productivity Indices, 1988 – 2010

Year	Multifactor productivity based on gross output	Real gross output	Combined units of all inputs	Labour compensation (dollars x 1,000,000)	Capital cost (dollars x 1,000,000)	Cost of intermediate inputs (dollars x 1,000,000)	Cost of energy input (dollars x 1,000,000)	Cost of material input (dollars x 1,000,000)	Cost of services input (dollars x 1,000,000)
1988	108.8	82.6	75.9	7079	3628.1	10947.6	2296.8	1529.6	7121.1
1989	104.8	82.7	78.9	7576.2	3150.9	12015.5	2393.5	1595.9	8026.1
1990	104.8	81.4	77.7	7927.2	2545.3	12372.4	2627.8	1708.2	8036.4
1991	100.1	74.4	74.3	8089.3	2620.5	11656.3	2365.9	1413.9	7876.4
1992	102.4	76.9	75.1	8127.4	2113.7	11894.8	2159.5	1610.7	8124.6
1993	102.3	76.6	74.9	8165.1	2475.9	11861.3	2118	1580.8	8162.5
1994	105.7	82.6	78.1	8082.4	3497	12587.1	2292.8	1696.2	8598.1
1995	104.1	85.1	81.7	8558.7	2781	14235.5	2514.8	1981.3	9739.4
1996	105.8	89.7	84.8	8490.2	3059.4	15374.7	2853	2027.2	10494.5
1997	107.4	96.2	89.6	9189.7	4517	16112.6	2867.5	2847.6	10397.4
1998	104.4	97.6	93.5	9751.5	4367.6	17075	2580.9	2991.2	11502.9
1999	104.8	100.8	96.2	10438.3	4660.5	17949.4	2697.8	3064.1	12187.5
2000	104.1	102.7	98.7	11110.3	4704.2	19532.2	3622.5	3084	12825.7
2001	103.3	101	97.7	11300.6	4609.1	19348.4	3433.7	2904.4	13010.3
2002	100	100	100	11669	4805.7	19889.8	3278.9	3107	13503.8
2003	100.6	101.4	100.8	10462.1	5510.5	20551	3325.9	3187.8	14037.2
2004	102	108.5	106.4	10959.3	5731.6	22930.1	4316.9	3290.1	15323.1
2005	106.9	113.3	105.9	11752.3	7380.9	23845.2	5678.4	3138.5	15028.3
2006	108.1	117.4	108.6	12430.8	8242.1	25488.3	6225.4	3333.8	15929.1
2007	106.9	120.3	112.5	12926.9	8437.4	27655.3	6753.9	3649.5	17251.9
2008	107.3	124.8	116.3	13245.1	8282.1	31287.8	9294.2	3997.6	17996

Table 5: Statistics Canada Productivity Data, Cansim table 383-0022, Air, rail, water and scenic and sightseeing transportation and support activities for transportation, 1988 – 2008

Year	Sectoral Output	Capital Services	Labor Hours	Capital Hours Ratio	Intermediate Inputs	Energy	Materials	Purchased Services	Combined Inputs	Multifactor Productivity
1988	55.9	51.1	91.8	55.7	105.7	N.A.	N.A.	N.A.	95.4	58.6
1989	56.6	52.1	101.0	51.6	107.6	N.A.	N.A.	N.A.	99.2	57.0
1990	58.7	53.3	111.3	47.9	105.7	N.A.	N.A.	N.A.	101.1	58.1
1991	57.5	54.3	107.1	50.7	102.8	N.A.	N.A.	N.A.	98.2	58.5
1992	61.0	56.7	106.2	53.4	100.7	N.A.	N.A.	N.A.	97.0	62.8
1993	63.0	59.4	119.0	50.0	103.1	N.A.	N.A.	N.A.	102.4	61.5
1994	67.2	61.5	118.8	51.8	101.1	N.A.	N.A.	N.A.	101.6	66.1
1995	70.1	64.7	116.2	55.7	106.8	N.A.	N.A.	N.A.	104.8	66.9
1996	74.9	69.7	119.6	58.3	113.7	N.A.	N.A.	N.A.	110.7	67.7
1997	78.5	76.5	123.3	62.1	115.0	107.0	215.2	115.0	114.0	68.8
1998	80.1	85.1	126.5	67.3	124.6	102.4	231.0	128.1	122.1	65.6
1999	84.0	93.0	119.6	77.7	123.2	127.5	196.6	121.6	120.6	69.6
2000	89.2	100.0	119.8	83.5	124.9	122.4	206.5	125.1	122.5	72.9
2001	83.3	106.9	118.4	90.3	113.8	111.7	156.7	114.9	115.7	72.0
2002	81.8	108.7	109.2	99.6	97.2	95.4	121.5	98.6	102.3	79.9
2003	84.9	106.0	102.2	103.7	104.5	94.3	135.6	108.5	103.9	81.8
2004	95.0	102.9	101.0	101.9	101.5	92.9	140.4	104.6	101.5	93.6
2005	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
2006	101.5	98.1	91.5	107.3	99.8	93.5	118.5	103.2	97.2	104.4
2007	104.7	96.1	87.5	109.7	106.9	118.6	166.7	96.5	100.0	104.7
2008	101.6	96.3	81.0	118.9	100.0	105.2	161.0	94.9	93.9	108.2
2009	95.0	95.5	76.7	124.5	88.2	93.1	104.4	84.6	85.4	111.2
2010	99.2	94.2	83.8	112.4	92.1	96.7	114.4	88.5	89.7	110.6

Table 6: Bureau of Labor Statistics American Airline Productivity Indices, NAICS 481, 1988-2010 (2005=100.0)

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