PRODUCTIVITY TRENDS AND DETERMINANTS IN CANADA

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1. Introduction

In this opening paper for the Workshop, I will cover only 3 topics:

- What is the evidence on economy wide productivity growth for the U.S. and Canadian economies over the years 1962-1998?
- What proportion of the growth in real output in Canada for the above years is due to Total Factor Productivity (TFP) growth and what proportion is due to the growth of primary inputs and changes in the terms of trade?
- What are the factors that "explain" TFP growth?

The above 3 topics will be covered in sections 2,3 and 4 below. It should be mentioned that in section 2, we will review both the growth of labour productivity (output per hour worked) in the U.S. and Canada and the growth of TFP.[1] Total Factor Productivity is the ratio of an index of outputs produced by the economy divided by an index of inputs used by the economy. We regard TFP as being the more accurate productivity measure because labour productivity can increase if capital input increases dramatically but at the same time TFP can fall.[2]

2. Trends in Canadian and U.S. Productivity, 1962-1998.

In this section, we will compare Canadian and U.S. labour productivity and total factor (or multifactor) productivity for the years 1962-1998.

For the U.S economy, the two productivity series are readily available from the Bureau of Labor Statistics website. For the Canadian economy, Coulombe (2000) has shown that the official Statistics Canada estimates of total factor productivity are not comparable with the corresponding U.S. estimates for three reasons:

- U.S. estimates of labour input are based on a detailed demographic model of labour supply whereas Canadian estimates of aggregate labour input are based on an aggregate of industry inputs of labour;

[1] However, we will not actually compare the level of output in Canada with that of the U.S. This is done in Lee and Tang (2000).
[2] In practice, labour productivity and Total Factor Productivity usually move in the same direction.

- Statistics Canada estimates of multifactor productivity do not include the contributions of inventory and land as inputs in the production process whereas the U.S. estimates do include these contributions;
- Statistics Canada depreciation rates for the components of reproducible capital are considerably higher than corresponding U.S. depreciation rates, leading to a *slower* growth of aggregate Canadian input and a *faster* growth of total factor productivity in Canada compared to the U.S.

The third factor is the most important source of difference in methodology between the U.S. and Canadian statistical agencies.[3] It is not certain who is correct (on the magnitude of depreciation rates in the U.S. and Canada) but it seems likely that the actual depreciation rates are not that different.

The difference in assumed depreciation rates between the U.S. and Canada is very large as Coulombe (2000; 11) notes:

"For the capital concept that excludes land and inventories, the aggregate implicit depreciation rate in the U.S. averages 4.4 percent between 1961 and 1997. This compares with the depreciation rate of 10 percent used to estimate the growth of Canada's business sector capital stock for MFP measurements. This is a big difference, to say the least. Such a difference in aggregate depreciation rates might be expected to have a large impact on the growth of capital stock and important implications for the measurement of MFP growth."

In an attempt to make the Canadian estimates of total factor productivity growth more comparable with U.S. estimates, we will assume that investments in nonresidential structures in Canada depreciate at a declining balance (or geometric) depreciation rate of 3.5% and machinery and equipment investments depreciate at a declining balance depreciation rate of 12.5%. This will lead to an average depreciation rate for reproducible capital in Canada that is somewhat higher than the corresponding U.S. rates but the rates will be much more comparable.

Including land and inventories as productive inputs instead of excluding them will tend to *reduce* the rate of growth of aggregate capital input and thus the Statistics Canada estimate of capital growth will tend to be *larger* than the corresponding U.S. estimate and hence the Canadian estimates of total factor productivity growth will tend to be *smaller* than the corresponding U.S. estimates due to the Canadian exclusion of these productive inputs. Coulombe (2000; 9-10) estimates the magnitude of this exclusion as follows:[4]

"By comparison to the U.S. approach, Statistics Canada's methodology imparts an upward bias to the measurement of capital stock growth and a downward bias to the calculation of MFP growth. We estimate that the effect of using a narrower definition rather than a broader concept of capital stock is to reduce the MFP growth rate by one-tenth of 1 percentage point per year over the 1961-97 period. While this is a small number, MFP annual growth rates are also modest, typically around 1 percent. Consequently, the underestimation amounts to approximately 10 percent of total annual MFP growth."

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[3] Coulombe (2000; 11) notes that "by applying BEA depreciation procedures, the growth of Canada's capital stock since 1980 increases by about one percent per year." Thus by applying U.S. depreciation rates, official Canadian multifactor productivity growth is reduced by about .3 to .35 percentage points per year over the last 20 years or so.

[4] Coulombe (2000; 22) notes that: "Diewert and Lawrence (1999), from a completely different methodology and using Canadian data only, arrive at exactly the same number. They estimate that the exclusion of land and inventories as inputs decreases multifactor productivity growth in Canada by 0.1 percent per year."

Thus putting aside the difference in labour input measures between the U.S. and Canada[5], Coulombe estimates that Canadian multifactor productivity estimates are around .25 percentage points per year *higher* than the corresponding U.S. estimates over the years 1961-1997 due to the differences in the definition of capital input and the differences in the assumed depreciation rates for the components of reproducible capital in the two countries.

Coulombe built up his estimates of Canadian MFP using estimates of industry output. However, industry estimates of output and intermediate input are rather fragile in all countries due to the lack of surveys on *intermediate input flows* and in particular, of *service flows* between industries. Hence, Diewert and Lawrence (1999) built up estimates of Canadian multifactor productivity growth using estimates of *final demand* (adjusted for commodity taxes), which they thought were more reliable. In this section, we will update their MFP estimates from 1996 to 1998. One problem with the Diewert and Lawrence estimates is that they used Statistics Canada depreciation rates for the components of reproducible capital in Canada. As was mentioned above, in the present paper, we will use depreciation rates that are closer to the U.S. rates.[6] For a description of the data sources and methodology that we are using, see Diewert and Lawrence (1999). For a listing of the major output and input series, see Appendix 1 below.[7]

Table 1 below lists labour productivity for Canada (LP_{CAN}) and for the U.S. (LP_{US}) for the years 1962-1998. These series represent estimates of private sector gross domestic product divided by a measure of private business sector labour input.[8] Table 1 also lists estimates of Total Factor Productivity for Canada (TFP_{CAN}) and for the U.S. (TFP_{US}) for the years 1962-1998. These series represent estimates of private sector gross domestic product divided by a measure of private business sector labour input and capital input. The U.S. series are taken from the Bureau of Labor Statistics website.

[5] Gu and Ho (2000) construct a Canadian labour input series that is a counterpart to that used by the BLS.

[6] There are some other differences in the data used in this paper compared to Diewert and Lawrence (1999): (i) revised Statistics Canada data were used; (ii) in the present paper, data on investment back to 1926 were taken from Leacy (1983) (see series F19, F20, F43 and F44) and used for the years 1926-1961; (iii) in order to obtain starting capital stocks for nonresidential structures and for machinery and equipment in 1926, it was assumed that gross fixed capital formation in these components was growing at a 2 % per year rate in the years prior to 1926 and we assumed that the declining balance depreciation rate for nonresidential structures was 3.5 % per year and for machinery and equipment was 12.5% per year. These assumptions gave us starting capital stocks that were roughly equal to the starting stocks listed in Leacy (1983) for 1926.

[7] The output series listed in this Appendix were built up from 34 detailed output series on 20 consumption components, 1 government component, 5 investment components, 5 export components and 4 import components covering the years 1962-1998. Chain Fisher ideal indexes were used to aggregate these detailed series into the usual national accounts type aggregates (but at producer prices rather than final demand prices). Statistics Canada data were used throughout the data construction process.

[8] The labour productivity series have been normalized to equal unity in 1962. The Total Factor Productivity series do not have to be normalized because the value of input is equal to the value of output in each period.

Table 1: Estimates of Labour and Multifactor Productivity for the Years 1962-98

Year	LP_{CAN}	LP_{US}	TFP_{CAN}	TFP_{US}
1962	1.0000	1.0000	1.0000	1.0000
1963	1.0200	1.0397	1.0174	1.0305
1964	1.0544	1.0870	1.0542	1.0712
1965	1.0852	1.1267	1.0840	1.1061
1966	1.1189	1.1720	1.1118	1.1395
1967	1.1337	1.1985	1.1127	1.1410
1968	1.1674	1.2363	1.1336	1.1701
1969	1.1913	1.2420	1.1505	1.1657
1970	1.2326	1.2665	1.1747	1.1628
1971	1.2605	1.3214	1.1931	1.2006
1972	1.2727	1.3648	1.2020	1.2355
1973	1.2858	1.4083	1.2207	1.2689
1974	1.2840	1.3837	1.2152	1.2224
1975	1.2994	1.4329	1.2153	1.2326
1976	1.3285	1.4839	1.2344	1.2805
1977	1.3970	1.5085	1.2800	1.3009
1978	1.3845	1.5255	1.2663	1.3169
1979	1.3805	1.5255	1.2607	1.3125
1980	1.3591	1.5198	1.2305	1.2834
1981	1.3818	1.5501	1.2386	1.2863
1982	1.4220	1.5444	1.2265	1.2471
1983	1.4558	1.5992	1.2428	1.2834
1984	1.4897	1.6446	1.2751	1.3256
1985	1.5158	1.6767	1.2975	1.3401
1986	1.5122	1.7278	1.2947	1.3619
1987	1.5364	1.7372	1.3149	1.3663
1988	1.5385	1.7580	1.3155	1.3750
1989	1.5466	1.7750	1.3093	1.3837
1990	1.5470	1.7996	1.2916	1.3852
1991	1.5793	1.8204	1.2913	1.3721
1992	1.6303	1.8904	1.3178	1.4041
1993	1.6268	1.8998	1.3111	1.4113
1994	1.6694	1.9263	1.3511	1.4259
1995	1.6685	1.9395	1.3497	1.4302
1996	1.7417	1.9924	1.3990	1.4535
1997	1.7837	2.0340	1.4228	1.4695
1998	1.7477	2.0888	1.3856	1.4913

The above series are graphed in Figure 1 below. The top line is U.S. labour productivity, the next line below it is Canadian labour productivity, the next line is U.S. Total Factor Productivity and the bottom line is Canadian Total Factor Productivity[9]. It can be seen that over the 37 year period, the U.S. productivity performance has been better than the Canadian one for both types of productivity. However, the more important TFP gap is not that large: at

[9] In the following section we indicate more precisely how our estimate of Canadian TFP was constructed.

the end of the 37 year period, U.S. TFP growth only exceeds Canadian growth by about 7.5%. U.S. labour productivity growth exceeds Canadian labour productivity growth by about 19.5% over the 37 year period.

It is useful to break down the productivity growth performance of the two countries into various subperiods. Our first subperiod covers the growth over the years 1963 to 1973 (11 years). These years are part of the "golden" years of productivity growth in both countries. The next period covers the "dismal" years, 1974 to 1991 (18 years in all). These were the years of the two energy shocks in 1974 and 1979-80, high inflation[10], and a world wide recession around 1991. Our final period covers the years 1992-1998 (7 years in all) where inflation subsided and there were no major recessions. Productivity growth rates were obtained from the data in Table 1 above by taking each year's level and dividing by the level of the previous year. These annual productivity growth rates were then averaged over the periods described above. The results are reported in Table 2 below.

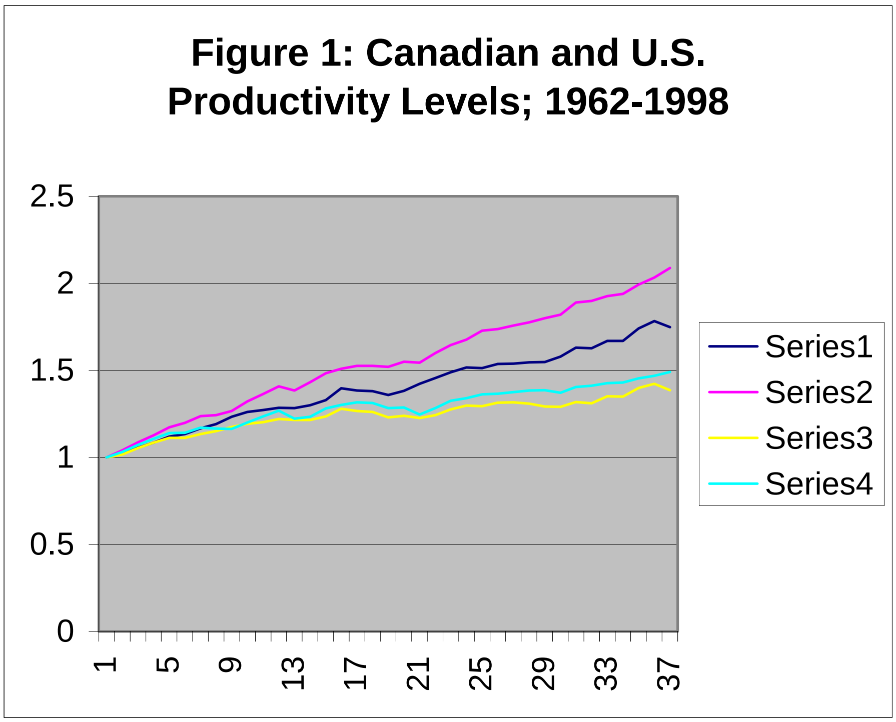

Table 2: Average Canadian and U.S. Productivity Growth Rates

Time Period	GLP_{CAN}	GLP_{US}	$GTFP_{CAN}$	$GTFP_{US}$
1963-1998	1.58%	2.08%	0.92%	1.13%
1963-1973	2.32%	3.17%	1.83%	2.20%
1974-1991	1.16%	1.45%	0.32%	0.45%
1992-1998	1.48%	1.99%	1.03%	1.20%

[10] Diewert and Fox (1999) argue that high inflation will tend to reduce productivity growth for a variety of reasons.

From Table 2, it can be seen that over the entire time period of 37 years, U.S. labour productivity exceeded that of Canada by .5% per year on average. For the more important Total Factor Productivity measure, U.S. TFP growth exceeded that of Canada by about 0.2 percentage points per year. In *absolute* terms, this does not seem like a large productivity gap, but given that the average TFP growth rate in both countries is only about 1 percent per year, this translates into a 20% *relative* gap. It can be seen that the golden years of productivity growth were indeed very good in both countries for the period prior to the first oil shock near the end of 1973, averaging about 2% per year in both countries. However, during the high inflation period, 1974-1991, this rapid rate of TFP growth fell dramatically in both countries to .32% per year in Canada and .45% per year in the U.S. Finally, in the "new economy" 1990's (the period 1992-1998), TFP growth has picked up in both countries, increasing to about 1% per year in Canada and to 1.2% in the U.S. However, these growth rates are still below the TFP growth rates achieved in the pre 1973 period.[11] Note that for all time periods, the U.S. appears to have had faster rates of productivity growth than Canada.

We turn now to an analysis of the relative contribution of TFP growth to the growth of real output in Canada.

3. The Sources of Real Output Growth in Canada

Kohli (1990) developed a very illuminating decomposition of a country's nominal GDP growth into various "explanatory" factors such as the growth of the country's domestic prices, of its export and import prices and its growth in primary inputs such as labour and capital.[12] We now explain how this methodology works.

Define q_D^t as the quantity of domestic final demand in period t and let p_D^t be the corresponding price.[13] Define q_X^t and q_M^t as the quantity of exports and imports in period t and let p_X^t and p_M^t be the corresponding prices.[14] Then nominal GDP in period t is defined as:

$$(1)\quad v^t \equiv p_D^t q_D^t + p_X^t q_X^t - p_M^t q_M^t .$$

We list the quantities that appear in equation (1) in Table 3 below. The q variables are in billions of 1962 dollars but v^t is in billions of current dollars.

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[11] Griliches (1979) and Diewert and Fox (1998) argue that current real output is surely higher than is measured by statistical agencies due to the lack of quality adjustment in the measurement of services. Since the service sector has been growing steadily since the "golden" years of productivity growth, it is likely that current TFP is higher than is currently being measured.

[12] Kohli's work draws on that of Diewert and Morrison (1986). See also Fox and Kohli (1998) for a recent application of this methodology to Australia.

[13] In our empirical work, q_D^t was defined as a chain Fisher ideal aggregate of 20 separate consumption series plus one government series and 4 investment series. See Diewert and Lawrence (1999) for a detailed description of these series.

[14] In our empirical work, q_X^t is a Fisher ideal chain aggregate of 5 Canadian export components and q_M^t is a fisher chain aggregate of 4 Canadian import components.

Table 3: Canadian Quantity Components of Nominal GDP, 1962-1998.

Year	v^t	$q_D{}^t$	$q_X{}^t$	$q_M{}^t$
1962	35477.2	36276.9	7458.8	8258.5
1963	37926.3	37461.8	8220.5	8683.2
1964	41678.2	40146.8	9419.6	9869.8
1965	46349.1	43651.5	9700.8	11006.3
1966	52196.2	46790.6	11079.2	12657.7
1967	56267.5	48016.2	12046.1	13161.5
1968	61087.1	50030.1	13515.1	14640.7
1969	66898.5	53031.8	14396.0	16536.6
1970	72220.9	53333.0	15964.3	16266.1
1971	78391.6	56299.3	16031.7	17349.8
1972	86188.6	59383.2	17358.2	19887.7
1973	101253.6	64005.3	19107.2	22908.5
1974	121324.8	68806.5	18434.6	25347.6
1975	140058.6	71543.2	17024.1	24613.7
1976	160296.3	75041.3	18454.6	26323.5
1977	178416.2	77877.6	19723.3	26445.1
1978	195773.1	79572.8	21579.3	27882.5
1979	223519.7	83155.9	22484.6	29906.6
1980	251934.3	84294.9	22523.9	30476.1
1981	289953.2	88673.4	22962.0	32656.9
1982	303370.4	82043.2	22863.6	27597.4
1983	325320.1	85061.9	24502.5	31255.9
1984	354912.4	89998.8	28848.9	36952.0
1985	381532.8	95346.7	30470.0	39900.3
1986	400868.5	99182.6	32338.3	43010.6
1987	441654.0	104224.5	34022.8	45306.2
1988	477976.4	109929.7	36729.0	51355.7
1989	511595.3	114203.5	36804.5	54477.2
1990	522898.4	112799.5	39157.3	55453.6
1991	521715.0	110896.9	40055.2	56670.4
1992	535229.8	112486.8	43248.8	59988.7
1993	550914.6	112495.6	48410.4	64996.2
1994	593111.9	117659.9	54678.8	71162.9
1995	621544.8	119301.3	59247.3	75749.0
1996	665807.1	124642.6	62733.7	79249.4
1997	696031.2	133170.2	67840.1	91332.8
1998	697560.0	133753.3	72724.5	96903.5

Looking at the last 3 columns of Table 3, we see that both exports and imports have grown much more rapidly than domestic demand in real terms. However, the growth in imports is much faster than the growth of exports. This is due to increasing imports of high tech equipment from the U.S. and other areas, which are falling in price. From Table 4 below, it can be verified that export prices are increasing faster than import prices; i.e., the terms of trade for Canada are improving over the period 1962-1998.

Table 4: Canadian Price Components of Nominal GDP, 1962-1998.

Year	p_D^t	p_X^t	p_M^t
1962	1.0000	1.0000	1.0000
1963	1.0228	1.0015	0.9929
1964	1.0447	1.0118	0.9924
1965	1.0825	1.0482	1.0058
1966	1.1342	1.0839	1.0177
1967	1.1782	1.1123	1.0414
1968	1.2169	1.1545	1.0517
1969	1.2728	1.2030	1.0836
1970	1.3259	1.2216	1.1062
1971	1.3824	1.2719	1.1429
1972	1.4580	1.3191	1.1711
1973	1.5798	1.5010	1.2459
1974	1.7994	1.9004	1.4802
1975	2.0253	2.1430	1.6787
1976	2.1788	2.2860	1.7244
1977	2.3219	2.4902	1.9482
1978	2.4880	2.7228	2.1863
1979	2.7065	3.1933	2.4523
1980	2.9535	3.7167	2.6494
1981	3.2638	3.9776	2.7802
1982	3.5395	4.0485	2.8837
1983	3.6989	4.0782	2.8552
1984	3.8291	4.1993	2.9997
1985	3.9345	4.2655	3.0973
1986	4.0420	4.2144	3.1693
1987	4.1960	4.2831	3.1208
1988	4.3447	4.2772	3.0518
1989	4.5252	4.3577	3.0395
1990	4.6456	4.3160	3.0680
1991	4.7387	4.1359	2.9903
1992	4.7744	4.2261	3.0772
1993	4.8851	4.3827	3.2434
1994	4.9733	4.6340	3.4489
1995	5.0107	4.9296	3.5419
1996	5.0688	4.9497	3.4889
1997	5.1212	4.9097	3.4930
1998	5.1528	4.8984	3.5900

Now use the above data to construct an implicit (chain) Törnqvist index of outputs, with q_D, q_X and $-q_M$ as the 3 quantities to be aggregated with price weights p_D, p_X and p_M respectively. This aggregate output index is to be divided by a Törnqvist index of 5 inputs and this is the TFP index, a^t say, listed in column 4 of Table 1. The 5 inputs are: labour, nonresidential structure services, machinery and equipment services, inventory services and business and agricultural land services. Denote the price and quantity of private sector labour input in period t by p_L^t and q_L^t respectively. Denote the declining balance user costs of the 4 types of capital input in period t by u_{NS}^t, u_{ME}^t, u_{IS}^t and u_{BAL}^t respectively.[15] Denote the quantity used of each of these types of capital in period t by q_{NS}^t, q_{ME}^t, q_{IS}^t and q_{BAL}^t. These data are listed in the Appendix.

Kohli (1990) shows that the nominal GDP in period t, v^t, has the following decomposition into "explanatory" factors if certain conditions on the country's technology hold:[16]

(2) $v^t = v^1\, a^t\, b_D^t\, b_X^t\, b_M^t\, c_L^t\, c_{NR}^t\, c_{ME}^t\, c_{IS}^t\, c_{BAL}^t$

where v^1 is nominal GDP in a base period (period 1), a^t is the *Törnqvist TFP index* for period t (see column 4 of Table 1), b_D^t , b_X^t and b_M^t are the *translog price effects* defined in Diewert and Morrison (1986; 666) and c_L^t , c_{NR}^t , c_{ME}^t , c_{IS}^t and c_{BAL}^t are the *translog quantity effects* defined in Diewert and Morrison (1986; 667). Each price effect represents the effect on period t nominal GDP due to the change in the price of domestic output going from period t −1 to period t (this is the b_D^t price effect), the price of exports (this is the b_X^t effect) or the price of imports (this is the b_M^t effect). Each quantity effect represents the effect on period t nominal GDP due to the change in the quantity of each primary input going from period t −1 to period t. The logarithmic change in the nth price effect going from period t −1 to t is defined empirically as follows:

(3) $\ln (b_n^t/b_n^{t-1}) \equiv (1/2)[s_n^{t-1} + s_n^t] \ln (p_n^t/p_n^{t-1})$; n = D, X or M

and the period t expenditure shares for (net) output n is defined as

(4) $s_D^t \equiv p_D^t q_D^t/ v^t$; $s_X^t \equiv p_X^t q_X^t/ v^t$ and $s_M^t \equiv -p_M^t q_M^t/ v^t$.

The logarithmic change in the nth quantity effect going from period t −1 to t is defined empirically as follows:

(5) $\ln (c_n^t/c_n^{t-1}) \equiv (1/2)[\sigma_n^{t-1} + \sigma_n^t] \ln (q_n^t/q_n^{t-1})$; n = L, NR, ME, IS and BAL

where the period t expenditure shares for primary input n is defined as

(6) $\sigma_L^t \equiv p_L^t q_L^t/ v^t$; $\sigma_{NR}^t \equiv u_{NR}^t q_{NR}^t/ v^t$; $\sigma_{ME}^t \equiv u_{ME}^t q_{ME}^t/ v^t$; $\sigma_{IS}^t \equiv u_{IS}^t q_{IS}^t/ v^t$ and $\sigma_{BAL}^t \equiv u_{BAL}^t q_{BAL}^t/ v^t$.

Definitions (4) and (6) along with the period 1 normalizations for the $b_n^1 = 1$ and the $c_n^1 = 1$ serve to define the b_n^t and the c_n^t for all periods t = 1,2,…,37. Since we assume that the quantity of business and agricultural land is fixed, the quantity effect c_{BAL}^t is always equal to 1 and hence can be ignored in the decomposition (2). The remaining price and quantity effects are listed in Table 5 below.

[15] These user costs are explained in Diewert and Lawrence (1999) and in the Appendix.
[16] Essentially, the technology of the country has to be representable by a certain translog profit function; see Diewert and Morrison (1986) or Kohli (1990) for the details. The assumptions do not appear to be very restrictive.

Table 5: GDP Price and Quantity Effects for Canada; 1962-1998.

Year	b_D^t	b_X^t	b_M^t	c_L^t	c_{NR}^t	c_{ME}^t	c_{IS}^t
1962	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1963	1.0232	1.0003	1.0016	1.0152	1.0060	1.0014	1.0023
1964	1.0453	1.0026	1.0018	1.0412	1.0120	1.0037	1.0036
1965	1.0836	1.0106	0.9986	1.0673	1.0194	1.0081	1.0049
1966	1.1363	1.0182	0.9957	1.0935	1.0274	1.0143	1.0080
1967	1.1809	1.0244	0.9901	1.1107	1.0365	1.0226	1.0109
1968	1.2197	1.0338	0.9877	1.1212	1.0441	1.0297	1.0118
1969	1.2759	1.0449	0.9801	1.1388	1.0509	1.0343	1.0134
1970	1.3288	1.0491	0.9749	1.1413	1.0573	1.0395	1.0166
1971	1.3847	1.0604	0.9669	1.1539	1.0643	1.0442	1.0173
1972	1.4602	1.0706	0.9608	1.1773	1.0710	1.0485	1.0179
1973	1.5824	1.1092	0.9445	1.2210	1.0773	1.0531	1.0181
1974	1.8046	1.1867	0.8976	1.2503	1.0842	1.0601	1.0188
1975	2.0378	1.2265	0.8641	1.2635	1.0914	1.0681	1.0214
1976	2.1966	1.2474	0.8574	1.2886	1.0993	1.0757	1.0224
1977	2.3434	1.2764	0.8280	1.2922	1.1064	1.0829	1.0246
1978	2.5132	1.3097	0.7998	1.3286	1.1137	1.0889	1.0274
1979	2.7359	1.3762	0.7710	1.3628	1.1209	1.0953	1.0289
1980	2.9850	1.4461	0.7519	1.3845	1.1294	1.1032	1.0307
1981	3.2964	1.4782	0.7405	1.4013	1.1391	1.1126	1.0296
1982	3.5683	1.4863	0.7328	1.3481	1.1490	1.1242	1.0301
1983	3.7229	1.4897	0.7347	1.3472	1.1568	1.1306	1.0276
1984	3.8498	1.5039	0.7242	1.3794	1.1633	1.1356	1.0269
1985	3.9533	1.5119	0.7168	1.4101	1.1694	1.1407	1.0284
1986	4.0604	1.5057	0.7114	1.4456	1.1757	1.1472	1.0292
1987	4.2143	1.5139	0.7150	1.4785	1.1809	1.1544	1.0297
1988	4.3628	1.5132	0.7202	1.5151	1.1862	1.1629	1.0306
1989	4.5450	1.5223	0.7212	1.5302	1.1923	1.1732	1.0312
1990	4.6667	1.5177	0.7190	1.5315	1.1982	1.1832	1.0321
1991	4.7607	1.4971	0.7250	1.4912	1.2034	1.1903	1.0317
1992	4.7967	1.5077	0.7181	1.4792	1.2078	1.1963	1.0314
1993	4.9080	1.5278	0.7045	1.4942	1.2104	1.2018	1.0316
1994	4.9959	1.5628	0.6874	1.5280	1.2131	1.2059	1.0313
1995	5.0324	1.6068	0.6798	1.5528	1.2166	1.2112	1.0321
1996	5.0882	1.6098	0.6841	1.5596	1.2202	1.2175	1.0332
1997	5.1389	1.6037	0.6838	1.5750	1.2241	1.2247	1.0364
1998	5.1702	1.6018	0.6749	1.6082	1.2290	1.2350	1.0402

Looking at Table 5, it can be seen that the smallest effects on GDP growth are due to the accumulation of inventories. The largest effects on nominal GDP growth are due to the changes in domestic prices (i.e., due to inflation). Comparing entries in Tables 4 and 5, it can be seen that the domestic price effect series, b_D^t, is virtually identical to the domestic inflation price series, p_D^t.

As we mentioned above, because the quantity of business and agricultural land was assumed to be constant in our study, the quantity effect c_{BAL}^t is identically equal to unity. Hence we can rewrite the decomposition of nominal GDP given by (2) above as follows:

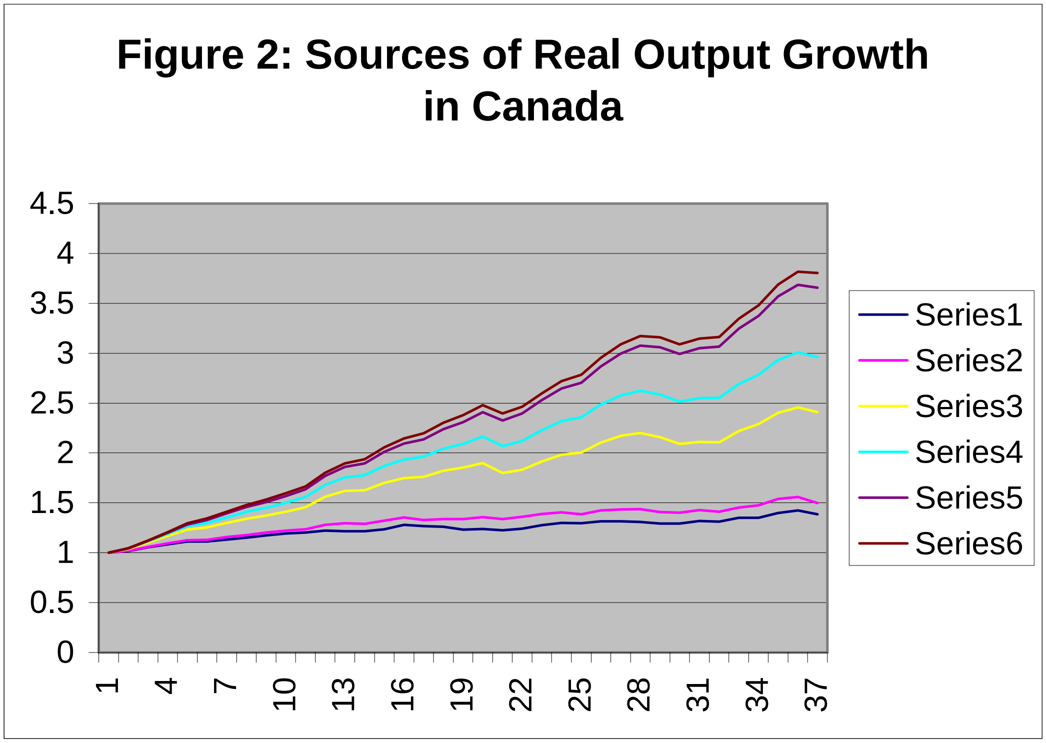
(7) $(v^t/v^1)/b_D^t = a^t\, b_X^t\, b_M^t\, c_L^t\, c_{NR}^t\, c_{ME}^t\, c_{IS}^t = a^t\, b_T^t\, c_L^t\, c_{NR}^t\, c_{ME}^t\, c_{IS}^t$

As was mentioned above, b_D^t, is essentially equal to the price of domestic output, p_D^t. Hence, the left hand side of (7) is essentially real GDP (normalized to equal 1 in the base period). On the right hand side, we have a series of factors that contribute to real growth; namely: *TFP growth* a^t , $b_T^t \equiv b_X^t\, b_M^t$ which is the combined effect *of changes in export and import prices* or *changes in the terms of trade*, *labour growth* c_L^t *, the growth of nonresidential structures* c_{NR}^t , *the growth in the use of machinery* c_{ME}^t *, and the growth in inventory stocks* c_{IS}^t. In Table 6 below, we start with TFP as a contributor to real output growth and then in the second column we table the combined effects of TFP growth and changes in the terms of trade (this is $a^t\, b_T^t$). In the third column, we add the effects of labour input growth; in the fourth column, we add the effects of growth in the stock of nonresidential structures; in the fifth column, we add the effects of growth in machinery and equipment stocks and in the sixth column, we add in the effects of inventory growth. The seventh column is $(v^t/v^1)/b_D^t$, normalized deflated GDP, which is indeed exactly equal to the sixth column. Figure 2 graphs these columns.

Table 6: The Decomposition of Real GDP into Growth Factors

a^t	$*b_T{}^t$	$*c_L{}^t$	$*c_{NR}{}^t$	$*c_{ME}{}^t$	$*c_{IS}{}^t$	$(v^t/v^1)/b_D{}^t$
1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1.0174	1.0194	1.0349	1.0411	1.0425	1.0448	1.0448
1.0542	1.0588	1.1025	1.1157	1.1198	1.1239	1.1239
1.0840	1.0939	1.1675	1.1902	1.1998	1.2057	1.2057
1.1118	1.1272	1.2326	1.2664	1.2845	1.2948	1.2948
1.1127	1.1286	1.2535	1.2992	1.3285	1.3430	1.3430
1.1336	1.1575	1.2978	1.3550	1.3953	1.4117	1.4117
1.1505	1.1781	1.3416	1.4100	1.4584	1.4779	1.4779
1.1747	1.2014	1.3712	1.4497	1.5070	1.5320	1.5320
1.1931	1.2233	1.4115	1.5022	1.5687	1.5958	1.5958
1.2020	1.2363	1.4555	1.5589	1.6345	1.6637	1.6637
1.2207	1.2789	1.5615	1.6822	1.7716	1.8036	1.8036
1.2152	1.2943	1.6182	1.7545	1.8600	1.8950	1.8950
1.2153	1.2879	1.6272	1.7759	1.8968	1.9373	1.9373
1.2344	1.3202	1.7012	1.8702	2.0119	2.0569	2.0569
1.2800	1.3529	1.7481	1.9341	2.0945	2.1461	2.1461
1.2663	1.3264	1.7622	1.9626	2.1371	2.1957	2.1957
1.2607	1.3377	1.8230	2.0434	2.2382	2.3028	2.3028
1.2305	1.3380	1.8525	2.0922	2.3081	2.3790	2.3790
1.2386	1.3559	1.9000	2.1642	2.4080	2.4794	2.4794
1.2265	1.3359	1.8009	2.0692	2.3263	2.3964	2.3964
1.2428	1.3603	1.8326	2.1200	2.3969	2.4631	2.4631
1.2751	1.3887	1.9155	2.2283	2.5304	2.5986	2.5986
1.2975	1.4062	1.9830	2.3190	2.6452	2.7203	2.7203
1.2947	1.3868	2.0048	2.3569	2.7039	2.7828	2.7828
1.3149	1.4233	2.1044	2.4850	2.8687	2.9540	2.9540
1.3155	1.4337	2.1722	2.5767	2.9964	3.0881	3.0881
1.3093	1.4375	2.1996	2.6226	3.0768	3.1728	3.1728
1.2916	1.4094	2.1584	2.5862	3.0600	3.1583	3.1583
1.2913	1.4016	2.0901	2.5152	2.9939	3.0890	3.0890
1.3178	1.4268	2.1106	2.5492	3.0496	3.1452	3.1452
1.3111	1.4111	2.1084	2.5521	3.0672	3.1640	3.1640
1.3511	1.4516	2.2180	2.6907	3.2447	3.3464	3.3464
1.3497	1.4742	2.2890	2.7849	3.3729	3.4813	3.4813
1.3990	1.5408	2.4029	2.9320	3.5698	3.6884	3.6884
1.4228	1.5601	2.4573	3.0079	3.6838	3.8178	3.8178
1.3856	1.4978	2.4088	2.9604	3.6561	3.8030	3.8030

	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr
East	20.4	27.4	90	20.4
West	30.6	38.6	34.6	31.6
North	45.9	46.9	45	43.9



The top line in Figure 2 represents the growth in real GDP in Canada for the years 1962-1998. The bottom line represents the contribution of TFP growth. The next line up represents the additional contribution of changes in the terms of trade. It can be seen that this contribution is much smaller than the effects of productivity growth. The next line represents the additional contribution to real output growth of labour input growth. It can be seen that this is the biggest contributor to real output growth of all of the sources of growth. Next comes the contribution of increases in the stock of nonresidential structures. This contribution is approximately equal to the contribution of increases in TFP. Next comes the contribution of increases in the stock of machinery and equipment. This contribution is also approximately equal to the contribution of TFP growth. The final line adds the contribution of growth in inventories; this contribution is rather small. Figure 2 shows at a glance that the main drivers of real output growth in Canada over the past 37 years are *growth in labour and capital input*. Unfortunately, growth in TFP has not been a very large contributor to overall Canadian output growth.

The above analysis does not tell us what the determinants of Canadian TFP growth were; it just tells us that over the past 25 years or so, TFP growth does not appear to have been very substantial. In the following section, we review a paper by Harris (1999) which attempts to map out what factors influence TFP growth.

4. The Determinants of Canadian Productivity Growth

Richard Harris (1999; 13-15) identified 3 main drivers of productivity growth:

- Investments in machinery and equipment.
- Investments in education, training and human capital development.
- Openness of the economy to international trade and direct foreign investment.

The above 3 drivers seem very reasonable. New knowledge is often embodied in new machines so "old" tasks can be performed more efficiently. Educating workers enables them to accomplish a wide variety of tasks more efficiently. An economy with high tariffs and import quotas will often have many other distortions that prevent prices from allocating resources efficiently. In theory, these efficiency losses induced by tariffs and taxes only affect the level of output and consumption and not productivity growth per se, but in practice, a highly distorted economy will usually not be an attractive one for undertaking research and development or for investing in new plant and equipment and hence productivity growth can suffer.

Harris (1999; 15-16) also looks at broader factors that might influence productivity growth. Some of the factors that he lists that I find very plausible are:

- Innovation; i.e., the development of new products and or processes somewhere in the world for the first time.
- Diffusion of innovations; i.e., the adoption of a new product or process in the local economy.
- Economies of scale. Many physical processes are more efficient when they are operated at a larger scale. Put another way, commodities are lumpy or at least they are sold in discrete lumps. I simply cannot buy very tiny amounts of most commodities. Put yet another way, the economy is filled with fixed costs. There are fixed costs of developing a new product, there are fixed costs in selling the commodity, there are fixed costs in transporting commodities, etc. As the scale of the market becomes larger, these fixed costs diminish as a proportion of the selling price and economic efficiency improves.[17]
- Spatial agglomeration or the growth of cities. Large cities allow specialized markets to develop both on the product side and on the skill side. In other words, in rural communities, the number of goods and services that can be purchased on local markets is limited[18] and producers may not be able to find specialized workers that they require. This point is related to the previous point: as cities grow, markets become larger and more specialization of labour is possible.[19]

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[17] Alfred Marshall (1898; chapter 11) is quite good on this point: "Again, it is true that when a hundred sets of furniture or clothing, have to be cut out on exactly the same pattern, it is worth while to spend great care on so planning the cutting out of the boards or the cloth , that only a few small pieces are wasted." Marshall (1898; 358).

[18] Of course, this situation is rapidly changing as far as goods are concerned due to the provision of goods and some services over the internet.

[19] Marshall (1898; 396) described his famous external economies of scale as follows: "Meanwhile an increase in the aggregate scale of production of course increases those economies, which do not directly depend on the size of individual houses of business. The most important of these result from the growth of correlated branches of industry which mutually assist one another, perhaps being concentrated in the same localities, but anyhow availing themselves of the modern facilities for communication offered by steam transport, by the telegraph and by the printing press."

- The provision of public infrastructure for transportation, communication and waste removal. This factor is very important when it is absent!
- Management practices. This explanatory factor could perhaps be subsumed under the diffusion of technology heading but I think Harris is right to give it a separate billing. In particular, the contribution of business consultants who bring information on global "best practices" to the local economy offer a relatively inexpensive way of increasing productivity dramatically.[20]
- High taxes (negative). Unless the revenues raised by high taxes are spent incredibly well, there will be deadweight losses and marginal excess burdens associated with high tax regimes. Again, this would seem to be a level effect and not necessarily affect TFP growth. However, in a world where some governments offer lower tax rates than other jurisdictions, economic activity and foreign investment will be attracted to the low tax locations and this will in turn stimulate TFP growth given the link between investment and TFP growth. Conversely, footloose investments will avoid high tax jurisdictions and TFP growth will suffer.[21]
- Small firms (negative). Small firms cannot afford large investments in research and development, they may not be able to specialize adequately and they may have large fixed costs. In general, very small firms will not be as efficient as large firms. In spite of this, governments tend to favour small firms and penalize large firms in all sorts of ways.[22]
- Labour market flexibility (positive). This point fits in with the second main driver of productivity growth that Harris identified earlier. Recent reforms to the Canadian system of unemployment insurance[23] very modestly penalized repeat users of what is now called employment insurance. These reforms were necessary in order to move the old unemployment insurance system away from a very hefty subsidy for seasonal workers and towards a system that would provide temporary relief for a worker who (permanently) lost his or her job. However, it is proving to be difficult for governments to live with the new regime even though it improves labour market flexibility.
- Low inflation (positive). It seems difficult to make the case that this factor would greatly influence productivity growth. But when one looks at the recent economic history of OECD countries, one is struck by the empirical fact that virtually every country experienced a dramatic drop in TFP growth during the years 1974-1991 and at the same time, a big increase in inflation occurred. Diewert and Fox (1999) identify a couple of mechanisms whereby higher inflation might translate into lower rates of TFP growth: (i) business income tax systems were not generally indexed for the effects of inflation and so businesses that used capital inputs with low depreciation rates were unfairly penalized and (ii) multiproduct businesses probably did not price their products correctly in periods of high inflation. The debate on this topic is still open but we do seem to be seeing a resurgence of TFP growth in recent years as inflation remains low in most OECD countries.

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[20] Harris (1999; 19) later makes the following point: "There is a growing body of evidence that the growth process is fundamentally driven by the *relocation of resources from low-productivity growth activities to high-productivity growth activities, rather than by limits on the availability of new technology*". I totally agree with this point. For some evidence on the vast differences in productivity that can result from firms using essentially the same technology, see Diewert and Nakamura (1999).

[21] Many British Columbia private sector economists contrast the high tax policies of B.C. with the lower tax policies in Alberta and attribute the relative increase in investment in Alberta to this factor. The Irish economy is another economy that has experienced a boom due in part to its low rates of business taxation.

[22] In Canada, small firms pay a lower rate of business income tax and they are not subject to many rather onerous programs that governments reserve for large firms.

[23] See Nakamura and Diewert (2000).

The above discussion will probably suffice to give the flavour of the work of Richard Harris on productivity. As can be seen from the above discussion of his points, I pretty much agree with him. Basically, we have some pretty good ideas of what factors will influence productivity growth but firm evidence on most factors is lacking.

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