Appendix: Decompositions of Aggregate Labour Productivity Growth

A first step in the identification of the principal causes behind Canada's dismal productivity performance since 2000 is to decompose productivity growth into its main accounting components. Such an exercise provides important insights to guide a more behavioural analysis of factors affecting labour productivity. In this appendix we undertake three major decompositions. First, we decompose labour productivity growth into its main sources for both Canada and the United States using the standard neoclassical growth accounting framework. We then proceed to a provincial decomposition of Canada's labour productivity growth followed by an industry-based decomposition. A set of tables detailing the industry and provincial decompositions can be found at the end of the appendix.

Neoclassical Growth Accounting

Using the neoclassical growth accounting framework and official estimates from Statistics Canada and the Bureau of Labor Statistics (BLS), we examine the sources of productivity growth over the 1961-2006 period.[1] The first section focuses on the sources of productivity growth in Canada and the United States in recent years, focusing on the 1996-2000 and 2000-2006 sub-periods. It is followed by a detailed analysis of historical trends in Canada and the United States since 1961 over six sub-periods, with an emphasis on the contrast between trends since 2000 and long term trends established in the 1973-2000 period.

Growth Accounting in Canada and the United States since 1996

Applying a growth accounting decomposition to both the 1996-2000 and 2000-2006 sub-periods reveals once again that while labour productivity in the two countries followed similar patterns in the 1996-2000 period, their post-2000 performance diverged significantly. In the 1996-2000 period, both Canada and the United States enjoyed strong productivity growth. In both countries, about half of productivity growth was explained by changes in measured productivity inputs, that is either by an improved labour composition[2] or an increase in the intensity of capital services (which includes both changes in capital stock and capital composition) (Table A).

---

[1] Baldwin and Gu (2007) have also done a growth accounting decomposition using these data focused on the 1996-2006 period rather than particularly on developments since 2000. Our analysis extends only to 2006 as Statistics Canada KLEMS data for 2007 are not yet available.

[2] Labour composition is the ratio of labour input to hours worked. As such, labour composition reflects the shifts in the educational attainment and work experience of the workforce. Labour input is calculated by aggregating the labour input of three broad categories of educational attainment (primary or secondary education, some or completed postsecondary certificate or diploma and university degree or above). The labour input of each educational category is a chained-Fisher aggregation of hours worked of those workers classified by work experience and class of workers (paid workers versus self-employed and unpaid family workers), using hourly compensation as weights. Note that hours worked are used to calculate labour productivity growth, not the adjusted labour input which includes changes in labour composition.

Between 2000 and 2006, however, Canada's labour productivity growth has been well below that of the United States (1.04 per cent versus 2.95 per cent). In Canada, labour composition contributed 0.32 percentage point, capital intensity contributed 0.84 percentage point and MFP contributed -0.10 percentage point. The contribution of each factor was larger in the United States, with labour composition contributing 0.38 percentage point, capital intensity 0.90 percentage point and MFP 1.66 percentage point.

Interestingly, the contribution of labour composition and capital services in absolute terms was almost identical in the United States and in Canada over the 2000-2006 period (1.28 point versus 1.16 point). Indeed, the key difference lies in the contribution of multifactor productivity (MFP), which is 1.76 percentage point larger in the United States than in Canada, accounting for almost all of the 1.91 percentage point labour productivity growth difference over the 2000-2006 period.

Table A: Sources of Growth in the Business Sector in Canada and the United States 1996-2000 and 2000-2006

	Canada		United States		Canada minus United States	
	1996-2000	2000-2006	1996-2000	2000-2006	1996-2000	2000-2006
Average Annual Rate of Growth						
Output	5.81	2.51	4.83	2.86	0.98	-0.34
Total Hours	2.69	1.45	2.10	-0.09	0.58	1.54
Labour Composition	0.70	0.53	0.38	0.55	0.32	-0.01
Capital Services	5.34	3.45	5.99	2.88	-0.65	0.56
Capital Services Intensity	2.59	1.97	3.81	2.98	-1.22	-1.01
Average Annual Percentage Point Contributions to Labour Productivity Growth						
Labour Productivity	3.05	1.04	2.67	2.95	0.38	-1.91
Labour Composition	0.41	0.32	0.26	0.38	0.15	-0.06
Capital Intensity	1.06	0.84	1.18	0.90	-0.12	-0.06
Multifactor Productivity	1.56	-0.10	1.22	1.66	0.35	-1.76

Source: Calculations from the Canadian Productivity Accounts from Statistics Canada, Cansim Table 383-0021 for Canada. Bureau of Labor Statistics (BLS) Multifactor Productivity Program for the United States. Note that the BLS data is not entirely consistent with previous estimates as the most recent revisions to output have not yet been integrated in the BLS MFP program.

Comparing periods, it is also mostly the change in MFP growth between 1996-2000 and 2000-2006, with 0.44 percentage point per year acceleration in the United States and a 1.66 percentage point deceleration in Canada, that accounts for how Canada went from a 0.38 percentage point labour productivity advantage in 1996-2000 to a 1.91 percentage point lag in the 2000-2006 period. Yet again, explaining the cross-country MFP growth differential appears to be the key to solving Canada's recent productivity puzzle.[3]

[3] An interesting element to note, but which can explain only part of the cross-country difference in MFP growth, is the large implicit difference in capital share between Canada and the United States. In both sub-periods, capital services intensity in the United States has grown about 50 per cent faster than in Canada, yet is has only contributed slightly more to labour productivity than it has in Canada. These estimates

This growth accounting exercise, even though it identifies MFP as the main culprit for the dismal productivity growth in Canada since 2000 and for the Canada-US labour productivity growth gap, fails to identify the underlying reasons behind the diverging MFP growth rates. Even though MFP is often associated to technological progress, it is in fact a measure of our ignorance as it includes all effects which are not captured by either an improved labour force or an increase in capital services. As such, identifying MFP growth as the main driver of Canada-U.S. productivity differences is not particularly insightful.

A Long-term Growth Accounting Perspective of Productivity

With Canada's productivity growth since 2000 falling below historical trend, it is useful to take a look at longer term productivity trends in Canada to identify potential sources for this falling productivity performance. Table B provides growth accounting estimates for Canada for selected sub-periods since 1961.

The 1961-1973 period, which is part of the golden era of productivity growth, clearly stands out from later periods. In this period, Canada benefited not only from strong growth in the quality of its labour force (contributing 0.65 percentage point per year) and in capital intensity (contributing 1.60 percentage point per year), but also from high MFP growth (contributing 1.36 percentage point per year). The strong growth of productivity inputs during that period was never to be matched in following periods.

Yet, probably more relevant for comparison to the current period is Canada's performance during the 1973-2000 period. Labour productivity growth between 1973 and 2000 averaged 1.69 per cent per year. The contribution of labour composition was 0.36 point, that of capital intensity 1.15 point and that of MFP's only 0.18 point.

Comparing the recent productivity performance to that of the 1973-2000 period reveals that the slowdown in labour productivity growth since 2000 is not the result of any one single factor. Over the 2000-2006 period, labour productivity growth was 1.06 per cent, down by 0.63 percentage point compared to 1973-2000. Growth in labour composition decreased, with its contribution to labour productivity falling marginally by 0.04 percentage point per year (from 0.36 to 0.32). More importantly, both capital intensity growth and MFP growth decreased, and their contribution to productivity growth fell by 0.31 percentage point each when compared to the 1973-2000 period. Moreover, the decrease in capital services intensity was due both to slower capital stock

---

suggest that Canada's capital share is around 41 per cent while it barely reaches 31 per cent in the United States. Yet, even if Canada's share were equal to that the United States, its MFP would have been only 0.25 percentage point larger in the 2000-2006 period and the lion's share of the gap between the two countries would have still stemmed from differences in MFP. MFP measures remain rift with measurement issues and methodological choices can create substantially different results. In general, researchers outside of Statistics Canada generally obtain larger estimates, even when they attempt to replicate the methodology used to create official measures. For example, Diewert (2008) estimates MFP growth in Canada in the 2000-2006 period to be 0.34 per cent per year instead of the official -0.10 per cent.

growth and to slower capital composition growth. Indeed, the shift towards ICT capital has slowed since 2000 compared to previous periods, driving the slowdown in the contribution of capital composition. The historical growth accounting exercise suggest that the lacklustre productivity performance of Canada since 2000 relative to the 1973-2000 period can hardly be attributed to one single factor, but is rather the result of slower growth of both productivity inputs and MFP.

Table B: Sources of Labour Productivity Growth in the Canadian Business Sector Since 1961 Selected Periods

	1961-1973	1973-2000	1973-1989	1989-1996	1996-2000	2000-2006
Average Annual Rate of Growth						
Output	5.60	3.35	3.56	1.48	5.81	2.51
Total Hours	1.99	1.66	1.95	0.42	2.69	1.45
Labour Composition	1.04	0.60	0.54	0.67	0.70	0.53
Capital Services	6.37	4.65	5.31	2.76	5.34	3.45
Capital Stock	4.56	2.85	3.55	1.14	3.04	2.33
Capital Composition	1.75	1.75	1.69	1.60	2.23	1.10
ICT Capital Services	7.32	19.56	21.93	14.31	19.54	9.47
Non-ICT Capital Services	6.23	3.52	4.30	1.64	3.76	2.81
Capital Services Intensity	4.29	2.94	3.30	2.33	2.59	1.97
ICT Cap. Serv. Intensity	5.33	17.90	19.98	13.89	16.86	8.02
Non-ICT Cap. Serv. Intensity	4.24	1.86	2.35	1.22	1.08	1.36
Average Annual Percentage Point Contributions to Labour Productivity Growth						
Labour Productivity	3.58	1.66	1.57	1.06	3.05	1.04
Labour Composition	0.65	0.36	0.33	0.42	0.41	0.32
Capital Services Intensity	1.60	1.15	1.28	0.87	1.06	0.84
Capital Stock	1.14	0.70	0.86	0.36	0.61	0.57
Capital Composition	0.44	0.43	0.41	0.51	0.44	0.27
ICT Cap. Serv, Intensity	0.09	0.47	0.42	0.46	0.66	0.31
Non-ICT Cap. Serv. Intensity	1.51	0.68	0.87	0.42	0.40	0.53
Multifactor Productivity	1.26	0.15	-0.03	-0.23	1.56	-0.10
Average Annual Percent Contributions to Labour Productivity Growth						
Labour Productivity	100.0	100.0	100.0	100.0	100.0	100.0
Labour Composition	18.1	21.8	20.7	39.2	13.3	30.3
Capital Services Intensity	44.7	69.1	81.7	82.0	34.8	80.5
Capital Stock	32.0	42.3	54.7	34.0	19.8	54.3
Capital Composition	12.3	26.0	26.1	47.7	14.5	25.8
ICT Capital Serv. Intensity	2.6	28.2	26.6	42.8	21.7	30.0
Non-ICT Cap. Serv. Intensity	42.1	40.9	55.1	39.2	13.1	50.4
Multifactor Productivity	35.4	9.2	-2.1	-21.3	51.2	-9.6

Source: CSLS Calculations based on the Canadian Productivity Accounts from Statistics Canada, Cansim Table 383-0021.

Turning to the United States, we can again confirm that the key difference between the two countries since 2000 is the sustained and accelerating growth of MFP in

the United States (Table C). Faster MFP growth in the United States than in Canada was already a feature in the 1961-1973 period, but it was more than outweighed by much faster growth in Canada for labour composition and capital services. Even though both countries experienced a significant slowdown in MFP growth in the 1973-2000 period, MFP in Canada still grew significantly slower that in the United States. Again, stronger growth in capital services intensity and labour composition in Canada partly offset weaker MFP growth.

Table C: Sources of Labour Productivity Growth in the U.S. Business Sector Since 1961, Selected Periods

	1961-1973	1973-2000	1973-1989	1989-1996	1996-2000	2000-2006
Average Annual Rate of Growth						
Output	4.88	3.39	3.23	2.94	4.83	2.86
Total Hours	1.52	1.60	1.69	1.10	2.10	-0.09
Labour Composition	0.12	0.40	0.32	0.59	0.38	0.55
Capital Services	4.41	4.24	4.22	3.30	5.99	2.88
Capital Services Intensity	2.85	2.60	2.49	2.18	3.81	2.98
Average Annual Percentage Point Contributions to Labour Productivity Growth						
Labour Productivity	3.31	1.77	1.52	1.83	2.67	2.95
Labour Composition	0.08	0.27	0.22	0.40	0.26	0.38
Capital Services Intensity	0.89	0.81	0.77	0.70	1.18	0.90
Multifactor Productivity	2.32	0.68	0.52	0.72	1.22	1.66
Average Annual Percent Contributions to Labour Productivity Growth						
Labour Productivity	100.0	100.0	100.0	100.0	100.0	100.0
Labour Composition	2.4	15.3	14.3	22.0	9.5	12.8
Capital Services Intensity	26.9	45.9	50.7	38.1	44.1	30.5
Multifactor Productivity	70.0	38.3	34.5	39.3	45.6	56.1

Source: Bureau of Labor Statistics, Historical multifactor productivity measures.

The recent period spanning from 2000 to 2006 is notably different because the United States outperformed Canada in terms of MFP, labour composition and capital services contributions (Table A). In other words, Canada's historical advantage in productivity input growth, which generally offset its weaker MFP growth, seem to have come to an end. Most importantly, the United States significantly deepened the MFP growth gap with Canada compared to the 1973-2000 period. With Canada's productivity since 2000 suffering from a slowdown in both productivity inputs and MFP growth relative to 1973-2000, and with the United States instead experiencing a slight acceleration in productivity input growth and a significant increase in MFP growth, it is thus no surprise that a large labour productivity growth gap has opened between the two countries.

iii. Trends in Factor Prices

Trends in factor prices in Canada have changed significantly in recent years when compared to earlier periods. Most significantly, there has been a clear downward trend in the cost of machinery and equipment, with the private M&E investment deflator falling

3.4 per cent per year between 2000 and 2007. In comparison, the M&E investment deflator increased on average by 2.7 per cent between 1973 and 2000. The latter increase, however, occurred mostly between 1973 and 1982 over which period the price of M&E doubled. Over the following 20 years, the price of M&E was largely stable. Since 2002, benefiting from a fast increasing exchange rate, M&E prices in the country have fallen 23 per cent in only five years.

In the United States, private M&E prices have also been falling 1.1 per cent per year between 2000 and 2007. The fall was not as large as in Canada, but it came on the tail of an average annual decrease of 1.4 per cent in the 1989-2000 period. In other words, M&E prices in the United States have been steadily falling since the early 1990s, a trend which continued, albeit less rapidly, in the 2000s. This is a stark contrast with Canada whose businesses faced stable M&E prices in 1990s and have benefited from falling prices only since 2002.

Trends in hourly labour compensation have been steadier in both countries. In both Canada and the United States, nominal hourly compensation has increased at about the same speed in the 2000-2007 period than in the 1981-2000 period. With labour compensation increasing at the same rate as in earlier period since 2000, and with M&E prices falling rapidly in Canada, we could reasonably expect acceleration in the rate of substitution of capital for labour. Similarly, with M&E prices in the United States since 2000 falling less rapidly than in the previous decades, and with labour compensation increasing at about the same rate, one could expect slower rate of substitution between capital and labour. Yet, capital services intensity has grown slower in Canada between 2000 and 2006 than in earlier period. Conversely, in the United States, capital services intensity growth between 2000 and 2006 was faster than in earlier periods. The discrepancy between trends in factor prices and trends in capital services intensity may be due to a time lag between new price signals and business reactions. It might also be in part due to the belief that M&E prices will continue to decrease significantly in Canada, thus leading to the postponement of investment. Even if these hypotheses are plausible, the discrepancy remains unusual.

Industry and Provincial Perspectives on Canadian Productivity

Aggregate productivity levels can be expressed as the labour-input-weighted average of industry productivity. Aggregate productivity growth, however, is not simply a labour-weighted average of industry productivity growth as it is also affected by employment shifts and relative price shifts. The effect of reallocating labour across industries is straightforward; if labour is reallocated from below average productivity level industries to above average productivity level industries, the effect on aggregate productivity is positive. The effect of prices is not as obvious. In any given period, computing GDP (and thus productivity) requires aggregating heterogeneous and noncomparable units of output. To do so, they are weighted by their respective prices and we sum up each value to obtain an aggregate value. Then in order to obtain comparable values over time, the effect of prices is extracted by dividing by a general output price index. Yet, over time, prices in a given sector or industry might grow faster or slower

than that of the overall economy, and as such its weight in the future will be respectively larger or smaller. Since relative prices affect the weight of a given industry in nominal GDP, it is no surprise that they should in turn affect productivity levels and productivity growth. As such, if the output price of an above average productivity level industry is growing faster than that of the rest of the economy, ultimately the importance of that industry will be larger and aggregate productivity levels and productivity growth will be increased.

In this section, we used this basic intuition to decompose productivity growth in Canada since 1981 into its industrial and provincial components. Unlike in previous sections in which we compared Canada and the United States, we now focus only on Canada and we use total economy productivity measures as comprehensive business sector measures for productivity levels are not available for provinces and industries. We apply the decomposition formula developed by Tang and Wang (2004) which on one hand captures the effect of industry or provincial productivity growth and on the other measures the effect of changes in labour input shares and/or relative prices in that industry or province.

Industry Decomposition

Our total economy measure of labour productivity growth in Canada between 1981 and 2004 grew 1.32 per cent on average each year (Summary Table 1). Between 2000 and 2004, labour productivity growth was almost identical at 1.30 per cent per year (Summary Table 5).[4] In 1981, the two industries with the largest nominal output share were manufacturing (17.5 per cent) and finance, insurance, real estate, rental and leasing (FIRE) and management (15.3 per cent), with construction (7.7 per cent) far behind. Both manufacturing and FIRE and management recorded above average productivity growth between 1981 and 2004, at 2.05 and 1.75 per cent respectively. Yet, the diminishing importance of manufacturing, as illustrated by its falling labour input share and relative prices, reduces its positive impact on productivity to 0.16 percentage point per year while FIRE and management, whose relative size increased slightly, contributed 0.41 percentage point per year. All industries contributed positively, to the exception of construction (-0.01 percentage point per year) which recorded very low productivity growth (0.16 per cent per year) and agriculture, forestry fishing and hunting (-0.05 percentage point per year) which falling relative size more than offset positive productivity growth (2.47 per cent). Also noteworthy is the mining and oil and gas sector which only contributed 0.11 percentage point per year, with its share of productivity growth over the period (8.0 per cent) accounting for little more than its output share in

[4] The decomposition requires estimates of current dollar GDP. Given that 2004 is the most recent year for which nominal GDP at the industry level are available, the analysis stops in 2004. Moreover, in order to obtain detailed estimates of labour input, labour shares and relative productivity levels, we must use our own estimates of labour productivity. Indeed, Statistics Canada does not provide level estimates of labour productivity, only indexes of productivity growth. To construct level estimates, we use data from the labour force survey for hours worked, which explain why our estimates for this decomposition differ slightly from both official business sector and official total economy labour productivity measures. Measures for hours worked do not differentiate between business and non-business sectors, so our measures of labour productivity are at the total economy level.

1981 (7.1 per cent). Five industries, all in services, recorded negative productivity growth, but they all benefited from an increase in their relative size, leading to low but positive contributions to aggregate productivity.

The picture emerging over the 2000-2004 period was relatively different. Over that period, a dramatic increase in the price of oil and in employment in mining and oil and gas transformed negative productivity growth in the sector (-2.88 per cent per year) into a strong positive contribution to aggregate productivity growth (0.35 percentage point or 26.8 per cent of aggregate productivity over the period). At the same time, the structural shift in manufacturing together with negative productivity growth in the sector (-0.51 per cent per year) translated into a -0.57 percentage point contribution to aggregated productivity from that sector. The structural shift towards mining and oil and gas (Bradley and Sharpe, 2008) and away from manufacturing (Sharpe, Arsenault and Lapointe, 2008) both seemed to have gained even more traction after 2004. All other industries, to the exception of utilities, contributed positively.

One of the key differences between the 2000-2004 period and previous periods is that sectors with high capital intensity, especially manufacturing and the mining, oil and gas sector, have experienced important relative size changes. In fact, taking the sum of squares of relative size change effect as an indicator, we find that in no previous periods was there an equivalently large change in the structure of the economy.[5] Moreover, previous shifts generally involved a sharp increase in the importance of services, especially FIRE and management. Since 2000, however, important positive relative size changes (mining and oil and gas and construction) and negative relative size changes (manufacturing) occurred mostly in the goods sector. Because these sectors are in general more capital intensive than services, it would be no surprise if these important shift lead to a lengthier and costlier adjustment period.

Finally, one can not overemphasize the impact of the manufacturing sector's dismal productivity growth between 2000 and 2004 (-0.51 per cent per year). Indeed, in addition to a shrinking labour force, the sector that used to be one of the strongest engines of Canada's aggregate productivity with consistent above average productivity growth has literally collapsed, instead recording negative productivity growth in the 2000-2004 period.[6]

Provincial decomposition

The provincial decomposition reveals a similar story, with productivity growth between 2000 and 2006 accounted for mostly by the oil-rich province of Alberta while the manufacturing-intensive provinces of Ontario and Quebec recorded poor

[5] We used the relative size change effect reported on Appendix Tables 2-5 and computed a sum of squares of these effects at the 2-digits industry level. The periods covered are 1981-1989, 1989-1996, 1996-2000 and 2000-2004.

[6] The adjustment does seem to be taking place however, with manufacturing productivity growth in Canada rebounding in 2005 (3.8 per cent) due mostly to large lay-offs. Yet, the adjustment process has not yet come to an end as labour productivity in the sector declined in 2006 (-0.1 per cent per year) and then increased again in 2007 (1.9 per cent), still in the context of massive lay-offs.

performances (Summary Table 10). In Canada, only four provinces have a large enough size to significantly affect aggregate labour productivity: Ontario, Quebec, Alberta and British Columbia. British Columbia, despite a significant improvement in its recent productivity performance[7] (0.91 per cent in 2000-2006 compared to 0.44 per cent in 1981-2006) has had a relatively steady contribution to productivity growth in Canada as its stronger productivity performance in recent years was offset by a decline in relative size (Summary Table 6 and 10). Quebec has performed consistently below average, with labour productivity growth of 1.02 per cent per year between 1981 and 2006 and a slow but steady decrease in its relative size. These trends have also been observed in the shorter 2000-2006 period with labour productivity at 0.98 per cent and a continued decline in Quebec's employment share, leading to Quebec contributing -0.01 percentage point to aggregate productivity in Canada.

Yet, the core of the story is found in developments in Ontario and Alberta. Historically, Ontario has been the engine of productivity growth in Canada with productivity growth slightly over average (1.31 per cent over the 1981-2006 period) and increases in its national employment share. Between 1981 and 2006 Ontario contributed 0.62 percentage points to aggregate productivity in Canada, almost 50 per cent of the total. In recent years, however, Ontario suffered from a faltering manufacturing sector.[8] It has recorded much slower productivity growth over the 2000-2006 period (0.75 per cent) and has suffered from a falling labour input share and relative output price. Since 2000, its contribution to annual productivity growth has been only 0.02 percentage point.

With oil prices increasing at a breakneck pace and with the decline of the manufacturing sector, economic power in Canada has gradually shifted out away from Ontario and Quebec and towards oil-rich western provinces. Since 2000, Alberta with its growing share of national employment and increased relative prices of its output, along with its above average labour productivity level, has contributed 0.69 percentage point to aggregated productivity, more than three times its closest rival (British Columbia with 0.18 percentage point). Of course, this performance is driven largely by the structural shift towards the mining and oil and gas industry and likely will not be sustained in the long term. Moreover, while high oil prices have helped Alberta record a stunning performance, they have also put pressure on manufacturing-intensive provinces through their effect on the value of the Canadian dollar. In addition, by intensifying the restructuring of the economy, high oil prices might have inadvertently diverted firms' attention away from productivity enhancement and towards short-term structural adjustment.

---

[7] See Sharpe and Arsenault (2008) for a review of the state of key productivity drivers in British Columbia.

[8] Productivity in manufacturing in Ontario fell by an average of 0.75 per cent per year between 2000 and 2004. It rebounded in 2005 and 2006, but the 2000-2006 average annual rate of growth remained well below average at 0.51 per cent per year (CSLS *Labour, Capital and Total Factor Productivity by Industry for Canada and the 10 Provinces Database* available at http://www.csls.ca/data/ptabln.asp).

List of Tables