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Can Measurement Error Explain the Weakness of Productivity Growth in the Canadian Construction Industry?

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Abstract

According to Statistics Canada productivity estimates, the rate of growth of real output per hour in the construction industry in Canada over the 1981-2006 period was 0.53 per cent per year, one-third of the of the business sector average.
This report examines evidence for and against the hypothesis that measurement error explains this below average productivity performance. The report finds that the use of input cost indexes to adjust nominal output to obtain real output, instead of the more appropriate use of output price indexes, for certain sub-industries of the construction sector represents the most likely source of measurement error. This procedure may result in a downward bias to labour productivity growth in the construction sector of up to 0.44 percentage points per year. It is thus likely that measurement error explains some, but not all, of the gap in labour productivity growth between the construction industry and the business sector.

Résumé

Selon les estimations de productivité de Statistique Canada, le taux de croissance de la production réelle par heure dans l'industrie de la construction au Canada entre 1981 et 2006 a été de 0,53 % par année, un tiers de la moyenne du secteur des entreprises. Ce document examine les données susceptibles de confirmer ou d'infirmer l'hypothèse que cette productivité inférieure à la moyenne est imputable à une erreur de mesure. Le document révèle que l'utilisation d'indices de coûts des intrants pour transformer la production nominale en une production réelle, au lieu de l'utilisation plus appropriée d'indices de prix des extrants, pour certaines sous-industries du secteur de la construction, représente la source la plus probable d'erreur de mesure. Cette procédure risque d'entacher d'un biais à la baisse la croissance de la productivité du travail dans le secteur de la construction pouvant aller jusqu'à 0,44 point par année. Il est donc probable que l'erreur de mesure explique une partie mais non la totalité de l'écart de croissance de productivité du travail entre l'industrie de la construction et le secteur des entreprises.

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Executive Summary

Motivation

According to official Statistics Canada productivity estimates, the rate of growth of real output per hour in the construction industry in Canada over the 1981-2006 period was 0.53 per cent per year, one-third of the of the business sector average of 1.46 per cent. This puzzle was originally identified in Sharpe (2004). Construction industry practitioners have expressed scepticism over the Statistics Canada figures. Similar concerns about the reliability of official construction productivity estimates have been raised in other OECD countries. A number of studies have found significant productivity gains for many tasks in the construction industry, a result that appears inconsistent with the weak aggregate productivity gains in the industry recorded by Statistics Canada.

Objective

The objective of this study is to assess the reliability of the official Statistics Canada productivity estimates for the construction industry in light of the industry perspective that there have been significant labour productivity gains in the industry. Construction practitioners argue that Statistics Canada is failing to capture productivity gains in the construction because of measurement difficulties. This hypothesis is examined in depth in this study.

Evidence Supporting the Mismeasurement Hypothesis

At least five pieces of evidence suggest that official estimates of productivity growth may underestimate true labour productivity growth in the construction industry in Canada. These are the use of input cost indexes to deflate nominal output, strong construction productivity gains in other countries, significant task-based productivity gains, a possible failure to adjust construction output for quality improvements, and strong growth in the capital-labour ratio in construction.

Use of input-cost based deflators

The evidence suggests that Statistics Canada is overestimating the increase in the prices of goods produced by the construction industry, because it is using deflators based on the cost of inputs instead of the price of outputs. This overestimation of the increase in output prices is the strongest evidence that Statistics Canada's estimates of construction labour productivity growth may exhibit downward bias. US researchers have indentified a similar problem with US construction productivity statistics. Simply put, the faster prices rise, the more Statistics Canada must adjust downward (deflate) its estimates of productivity growth. If Statistics Canada overestimates the rise in prices, then it will underestimate real output and productivity growth.

In Canada, deflators used in the construction industry that are based on the cost of inputs (e.g. concrete, labour, wood products) have generally increased faster than those based on output prices (e.g. houses, warehouses, roads). For example, the input-cost based deflator for nominal output in engineering and repair construction, advanced at a 2.71 per cent average annual rate over the 1981-2003 period. In contrast, the output-price based deflator used for nominal output in non-residential building construction advanced at only a 1.78 per cent average annual rate, a difference of 0.93 percentage points. Given that engineering and repair construction represent about 48 per cent of total construction GDP, this in turn would increase output per hour growth in the overall construction industry by 0.44 percentage points per year, from around 0.53 per cent to 0.97 per cent. Thus an upper bound estimate on the role of measurement error in construction productivity growth would be 0.44 percentage points, which accumulates to a significant number over such a long period.

This upper-bound estimate of measurement error assumes that prices for non-residential building construction output are a reasonable proxy for prices for engineering and repair construction output. More work is required to determine the validity of this assumption. For now, this estimate of the upper bound of measurement error should be seen as suggestive and as an order-of-magnitude only.

Strong construction productivity gains in other countries

It is not inevitable that construction productivity growth be weak. Labour productivity growth in the construction industry in many countries was above 1.5 per cent per year over the 1979-2003 period. The UK construction industry, for example, experienced output per hour growth of 1.9 per cent per year. This situation may suggest that, if properly measured, construction productivity growth can be robust and that Canada's poor productivity performance may reflect mismeasurement. Of course, other factors might also account for faster construction productivity growth in other countries, so the use of large differences in productivity performance across countries to support the mismeasurement hypothesis is not conclusive.

Significant task-based productivity gains

Task- or activity-based productivity measurement involves measuring the change over time in the number of hours required to complete a specific task, e.g. installing 10 square meters of ceiling tile. If the number of hours required to perform the task falls, then all else being equal, productivity has improved.

Both the literature on productivity measurement in the construction industry and the construction practitioners interviewed for this report provided strong evidence that, on a task basis, there have been significant productivity gains in construction. Given the large number of construction tasks that many argue experienced gains, one might have expected that this would have translated into stronger productivity growth at the level of the industry and that the failure of such gains to appear is due to the inability of the statistical system to capture them because of measurement problems.

The counter-argument is that the number of tasks where productivity gains have been significant may indeed not have been that large, and therefore one would not expect a major impact on the overall rate of productivity growth in the construction industry. Moreover, at least one practitioner noted that productivity growth could be weak due to a lack of significant improvements in management and organization, coupled with the increasing complexity of some projects.

Failure to adjust construction output for quality improvements

It is recognized that price indices should be adjusted to take account of quality improvements, and that such adjustments can lead to much lower price increases and larger real output increases. This has been the case in the computer industry where massive quality improvements in computers have resulted in plummeting quality-adjusted prices and soaring real output. While the quality improvements in the output of the construction industry are certainly much less than in the computer industry, the construction industry practitioners interviewed for this study identified a significant number, such as more energy efficient buildings and lower-maintenance structures. If Statistics Canada has not made sufficient downward adjustment in construction price indexes to reflect these quality improvements, then real output and productivity may be underestimated.

Strong growth in capital-labour ratio in construction

A key driver of labour productivity is the increase in the capital stock with which each worker works. The rate of growth of the capital-labour ratio in the construction industry in Canada has been strong, averaging 2.57 per cent per year over the 1987-2004 period above the business sector average. Yet this increased capital intensity of production of the industry has not translated into labour productivity gains, which is surprising and a different result from that found in other industries. This may suggest that measurement error is at play.

Evidence Not Supporting the Mismeasurement Hypothesis

Evidence not supporting the mismeasurement includes weak construction productivity growth observed in other countries, rapid productivity growth in earlier periods, large provincial differences in construction productivity growth, the lack of evidence of a failure to capture the underground economy, and the lack of an effect of prework on construction productivity.

Weak productivity growth in other countries

It could be the case that labour productivity growth is inherently weaker in construction because of the one-off nature of much construction output. A large number of countries experienced very weak labour productivity growth in the construction industry over the 1979-2003 period. For example, the United States saw an average annual decline of 0.8 per cent in output per hour per year, while both Japan and Germany experienced slightly negative productivity growth in the construction industry. Of course, measurement problems might account for the dismal construction industry productivity performance in these countries. However, to the degree that the statistical systems of these countries are better in capturing true productivity gains than the Canadian statistical system, this situation may be due to the reality that productivity growth in construction is fundamentally slower than in other industries because of the labour-intensive nature of many construction tasks which are not amenable to mechanization.

Earlier periods of rapid construction productivity growth in Canada

Labour productivity in the construction industry in Canada advanced at the phenomenal rate of 5 per cent per year between 1974 and 1983. This suggests that our statistical system was fully capable of capturing construction productivity gains in the past and the fact that since 1983 it has recorded only weak gains suggests that they may just not be there to be recorded. Of course, measurement problems could have been at play in both periods. At the same time, evidence suggests that Statistics Canada did alter its measurement techniques for construction prices in the 1980s and 1990s. While outside the scope of this report, more research is required to determine how changing measurement techniques used by Statistics Canada have affected productivity estimates for the construction industry in Canada.

Large provincial differences in construction productivity growth

Estimates of construction productivity growth rates by province show very large differences ranging from -1.13 per cent to 0.69 per cent per year between 1987-2005. This suggests that factors other than measurement problems may be at play in explaining construction productivity growth. Of course, both measurement problems and other factors may be at work. Differences across provinces are not inconsistent with measurement problems.

Lack of evidence of a failure to capture the underground economy

It is widely recognized that much construction activity is not reported to the taxation authorities. But this does not mean that these transactions are not included through imputations in the estimates of nominal output for the construction industry produced by Statistics Canada. Indeed, our detailed analysis of the procedures used by Statistics Canada to estimate the nominal output of the industry suggests that the lion's share of underground activity is accounted for and that nominal output and (hence real output) is not underestimated. However, because of the clandestine nature of underground activity, one cannot say with full certainly that this is the case, but it is unlikely that underground activity is the cause of mismeasurement.

The lack of effect of prework on construction productivity

The report showed that the greater use of prework, defined as modularization, prefabrication and preassembly, in the construction industry, while resulting in productivity gains in terms of overall labour requirements for construction projects, has no *a priori* effect on output per hour in the construction industry itself, and, therefore, cannot account for mismeasurement of productivity gains. In addition, the stability of the ratio of current dollar intermediate goods to gross output suggests that the relative importance of prework has not increased over time in Canada.

Conclusion

This report makes a case that measurement error may account for much of the weakness in labour productivity growth in the construction industry in Canada over the last quarter century. The use by Statistics Canada of input-cost based deflators in the deflation of the nominal value of output in a number of construction sub-industries does introduce a significant downward bias into productivity estimates. A ballpark estimate of the upper bound of this bias would be 0.44 percentage points per year over the 1981-2006 period. This would raise output per hour growth in the construction industry from 0.53 per cent to 0.97 per cent and would eliminate about one-half of the gap in labour productivity growth between the construction industry and the overall business sector. It is important to stress that this estimate should be seen as suggestive and as an order-of-magnitude only.

Introduction[1]

According to official Statistics Canada productivity estimates, the rate of growth of real output per hour in the construction industry in Canada over the 1981-2006 period was 0.53 per cent per year, about one-third of the business sector average of 1.46 per cent. Construction industry practitioners have expressed scepticism over the Statistics Canada figures. Similar concerns about the reliability of official construction productivity estimates have been raised in other OCED countries. A number of studies have found significant productivity gains for many tasks in the construction industry, a result that appears inconsistent with the weak aggregate productivity gains in the sector recorded by Statistics Canada

The objective of this study is to assess the reliability of the official Statistics Canada productivity estimates for the construction industry in light of the industry perspective that there have been labour productivity improvements. Some industry practitioners argue that Statistics Canada is failing to capture productivity gains in the construction industry because of faulty measurement techniques. This hypothesis is examined in depth in this study.

This study is divided into five parts. Part I examines trends in productivity in the construction industry. It first provides an overview of the statistical framework in place in Canada to analyze productivity in the construction industry. It then surveys construction industry productivity trends in Canada on the basis of construction sub-industries and provinces. It examines construction productivity trends in the United States and other developed countries. Finally, it assesses the implications of productivity trends for productivity measurement.

Part II surveys the literature on the measurement of construction industry productivity. The review surveys US and Canadian literature chronologically in order to critically assess the state of knowledge on this issue.

Part III presents the results of a survey conducted by the Centre for the Study of Living Standards of seven expert construction industry practitioners from across Canada. The survey collected information on the perceptions of the practitioners on a wide variety of issues related to the measurement of construction industry productivity in Canada.

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[1] Peter Harrison who now is employed by Finance Canada is the principal author of this study, Jean-François Arsenault and Sharon Qiao also contributed. Andrew Sharpe supervised this project. The view expressed in this article are those of the author and do not necessarily reflect those of Finance Canada.This report was commissioned by the Construction Sector Council. Abridged versions published in English and French in Spring 2007 International Productivity Monitor. This paper was originally presented at a meeting of the Construction Sector Council on 28 February 2006 in Kelowna British Columbia and subsequently at the Canadian Economic Association in Montreal on 26 May 2006. The author would like to thank the participants and organizers of both sessions and especially George Gritziotis and Rosemary Sparks for support of the project and Pierre Fortin for comments.

Part IV is a critical review of the methodology currently employed by Statistics Canada to produce productivity estimates for the construction industry. Productivity is first carefully defined. Then specific issues that could potentially impact the measurement of productivity in the construction industry are examined including the underground economy, the deflation of nominal output, and the use of prework (prefabrication, modularization, and preassembly) in the industry.

Part V examines the hypothesis that measurement error explains the weakness in labour productivity growth in the Canadian sector over the last quarter century. It critically evaluates arguments that both support and go against the view that mismeasurement leads to the underestimation of the real productivity gains in construction. It concludes that measurement is likely an important factor in explaining the slow productivity growth in the construction industry in Canada.

What is Productivity?

Confusion sometimes arises because economists and businesspeople have different ideas about what productivity means. To businesspeople productivity often means an increase in sales or output per worker, leading to increased profit margins, measured in current dollars. Economists have a related, but different definition of productivity. They define productivity as the relationship between outputs of goods and services and inputs of resources, in both human and non-human form, used in the production process, with the relationship usually expressed in ratio form. Both outputs and inputs are measured in physical volumes and are thus unaffected by price changes. When the growth of output exceeds the growth of inputs, then productivity is said to be increasing. (Sharpe, 2002: 31)

One important distinction within the concept of productivity is between partial factor productivity and multifactor productivity. Partial factor productivity is the relationship between output and one input, usually, but not necessarily, labour or capital. Multifactor productivity (MFP) or total factor production (TFP) relates output with all of the inputs that can be measured. However, for the purposes of this study, labour is the most relevant input and will be the primary focus. Therefore, unless otherwise stated, productivity will refer to labour productivity.

Labour productivity can be measured in terms of output per hour worked or output per worker. When data availability permits, hours worked is the preferred measure of labour input, because it is more precise. Workers may work very different amounts of hours over time and across industries, countries, genders, ages and many other classifications. Harchaoui *et al.* (2001: 158) stress the importance of using hours given the rise of non-standard types of employment like part-time and self-employment that can affect the number of hours worked by each worker.

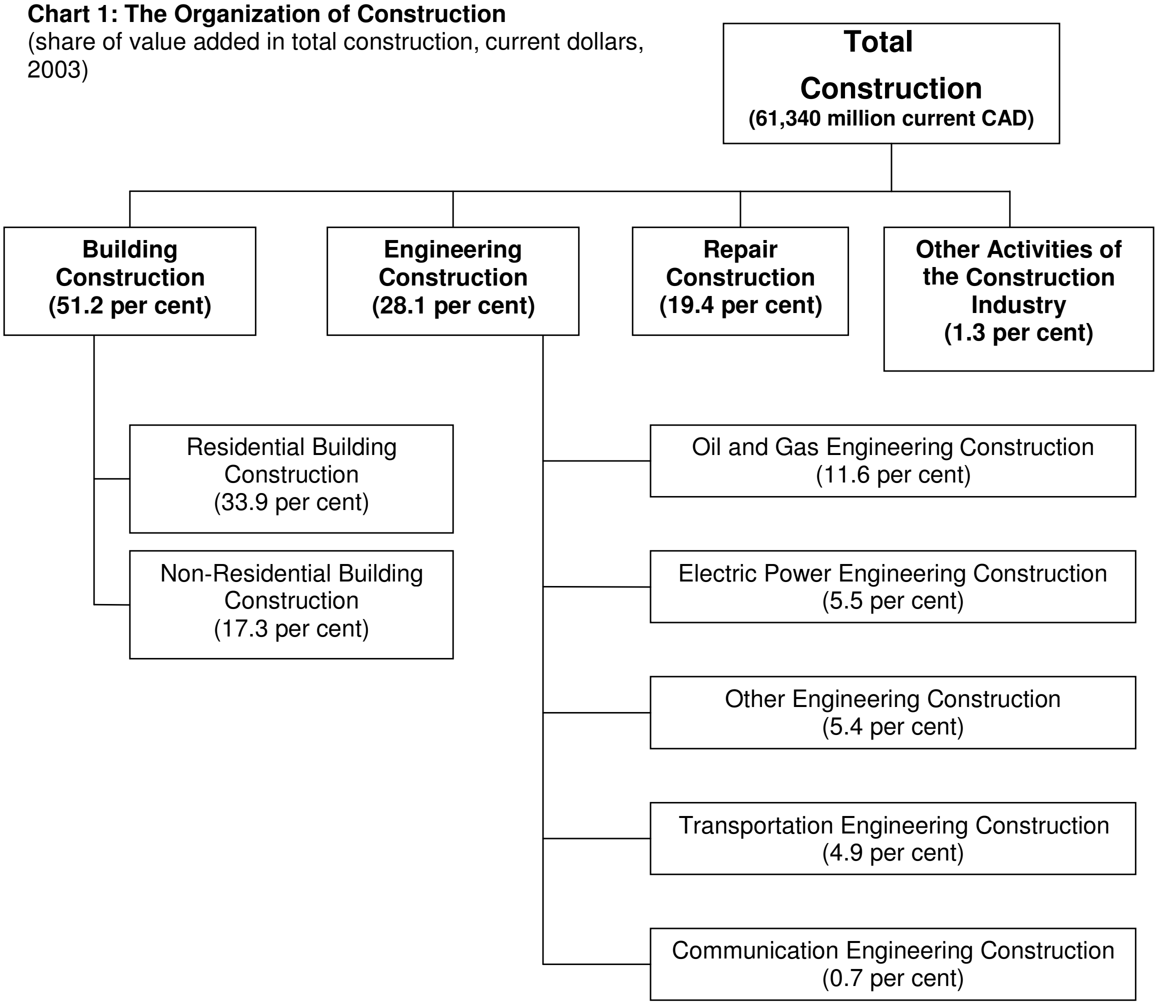
Another important distinction to make in productivity analysis is that between levels and growth rates. The former is the output per unit of input at a given point. For example, in the year 2001 the level or value of output per hour in the business sector in Canada was $30.06, expressed in constant 1992 prices. The latter refers to the percentage change in levels of output per hour, expressed in constant prices, between two points in time. An example would be the 20.4-per-cent increase in labour productivity in the business sector in Canada between 1989 and 2001. In 1989 output per hour was $24.97, $24.97 in 1998, and $30.06 in 2001. One often hears the complaint that Canada's productivity is poor. This could be in reference to a low aggregate productivity level, to a low productivity growth rates, or both. It is important to be clear about whether productivity levels or growth rate are being referred to as the implications can differ significantly (Sharpe, 2002: 35).

Output is measured as either value added or gross output. Gross output is simply the total value of all output produced by an establishment or industry. Value added is the value of the output of an establishment, less the value of all of the intermediate inputs that were used to produce that output. Various factors can influence the relationship between value added and gross output in any industry. For example, if a construction company chooses to have some work done by a manufacturing establishment rather than on site, value added will necessarily fall in the construction industry as the increased value of the pre-made components is subtracted from gross output. At the same time, value added in manufacturing will increase. However, the value of construction industry gross output may or may not fall, depending on whether the value of the intermediate inputs subtracted exceeds or does not exceed the value of the gain in total output. In this study, productivity data are presented on both a value-added and a gross-output basis, and, where relevant, differences between these measures are discussed. Value added is preferred in this paper, since it more accurately measures the true contribution to output of the construction industry.

Part I: Construction Industry Productivity Trends

This part is divided into five sections. The first section provides background information on the framework that is in place for analyzing productivity in the construction industry in Canada. The second section explores productivity trends in the construction industry in Canada. The third and fourth sections examine construction industry productivity trends in the United States and in other countries for which data are available. The fifth and final section offers some remarks on trends that could have implications for productivity measurement in the construction industry in Canada. Unless otherwise stated, productivity is labour productivity, measured on an output-per-hour basis.

Chart 1: The Organization of Construction
(share of value added in total construction, current dollars, 2003)



Note: 2003 is the most recent year for nominal output in construction.

The Organization of the Construction Industry in Canada

This section briefly reviews the organization of the construction industry in Canada as seen from the perspective of those who analyze productivity. This structure may be unfamiliar to some practitioners.

Construction is divided into three main sub-industries: building construction, engineering construction and repair construction. The fourth sub-industry, "Other Activities of the Construction Industry" is heterogeneous and very small (Chart 1), so it will not be included in this analysis. Building construction is further subdivided into residential and non-residential building construction. Engineering construction is subdivided into oil and gas, transportation, other engineering, electric power, and communication engineering construction.

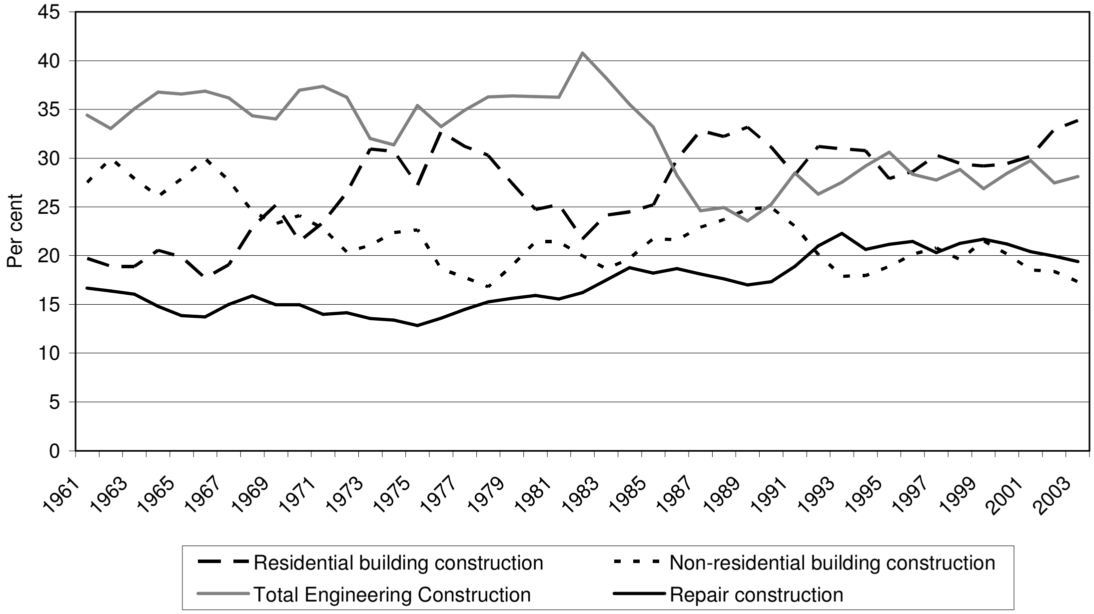
The sub-industries within the construction industry are not of equal size in terms of the value of output they generate. Based on value added data from 2003, the latest year for which current-dollar output data are available, residential construction was by far the largest sub-industry with 33.9 per cent of total value added. The next largest sub-industry was non-residential building at 17.3 per cent of value added. Together residential and non-residential building construction accounted for slightly more than half of total value added in the construction industry (51.2 per cent).

Engineering construction accounted for 28.1 per cent total value added in the construction industry. Within engineering construction, oil and gas engineering construction was the most important component at 11.6 per cent of construction value added. Electric power engineering (5.5 per cent), other engineering (5.4 per cent), transportation engineering (4.9 per cent), and communication construction (0.7 per cent) were the other components.

Repair construction constituted 19.4 per cent of construction industry value added. Other activities of the construction industry accounted for only 1.3 per cent of value added in 2003.

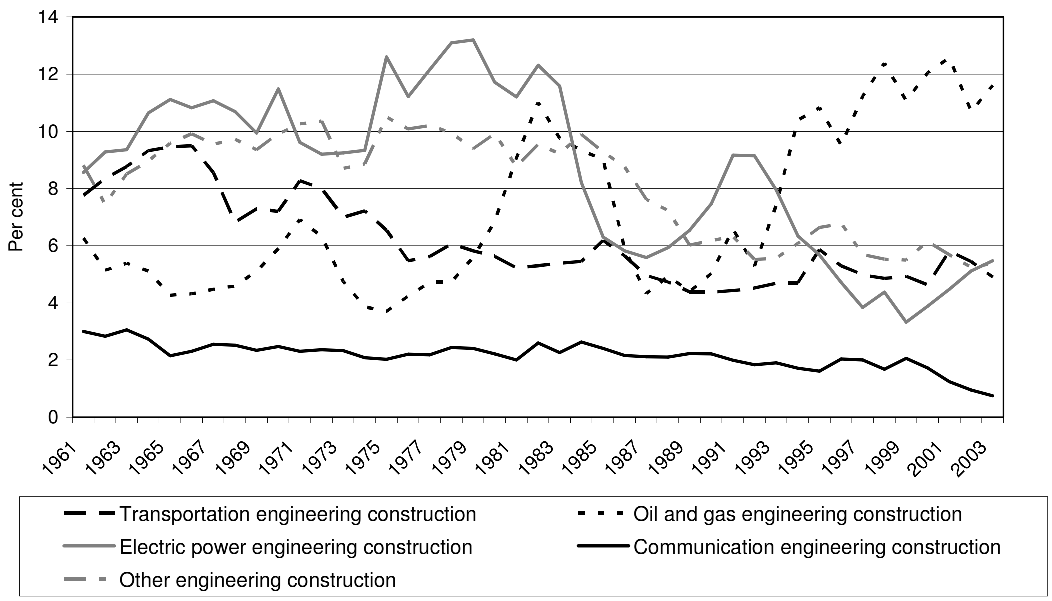
While looking at a snapshot of the composition of the construction industry in one year is informative, it does not provide a complete picture, since over time there have been important changes in the relative importance of different sub-industries (Chart 2). Interestingly, the high relative importance of residential construction is only a very recent trend, between 1961 and 1986 engineering construction was the most important sub-industry. Non-residential building construction has shown a fairly steady downward trend over the entire period. Repair construction has shown a slightly increasing trend during the 42-year period from approximately 17 per cent of total value added to approximately 19 per cent.

Chart 2: Shares of total output, construction industry, Canada, current dollars, per cent, 1961-2003



Source: Statistics Canada: CANSIM Table 379-0023.

Chart 3: Components of engineering construction as a proportion of total construction industry value added, current dollars, Canada, per cent, 1961-2003



Source: Statistics Canada: CANSIM Table 379-0023.

Within engineering construction there have been significant shifts in the relative importance of the sub-industries (Chart 3). The importance of oil and gas construction has waxed and waned with the state of the wider energy sector, with peaks in 1971, 1982, and a recent increase in importance beginning in the early 1990s. Electric power engineering construction has also changed in importance peaking in the late 1960s, late 1970s and early 1990s. Transportation engineering construction has gradually declined in relative importance since its peak in the mid 1960s. Both communications engineering and other engineering construction have exhibited downward trends between 1961 and 2003.

Construction Industry Productivity Trends in Canada[2]

This section first situates construction industry productivity in the context of the overall productivity performance of the Canadian business sector. It then examines trends in the performance of the construction industry in each of the ten provinces. Then the section turns to an examination of the key sub-industries of the construction industry. After that, it examines capital and total factor productivity in the construction industry. The main data sources for this section are Statistics Canada and the Centre for the Study of Living Standards database, based on Statistics Canada Labour Force Survey and National Accounts data.

Construction Industry and Business Sector Labour Productivity Trends

Based on output per hour data, in the 45 years since 1961, the productivity performance of the construction industry in Canada has been relatively poor in comparison with the productivity performance of the business sector as a whole (Chart 4).[3] Labour productivity in the construction industry today is about 60 per cent higher than it was in 1961. The key problem is the poor performance of the industry *relative* to the business sector, which has seen productivity increase two-and-a-half times since 1961.

The construction industry exhibited a very strong productivity performance between 1975 and 1983. Virtually all of the productivity growth in the construction industry in the period from 1961 to 2006 took place in the period between 1975 and 1983. The periods before and since have been disappointing. While business sector productivity has grown almost continuously between 1961 and 2006, construction industry productivity has suffered pronounced downward trends in the periods 1961-1967, 1971-1975, and 1984-1995.

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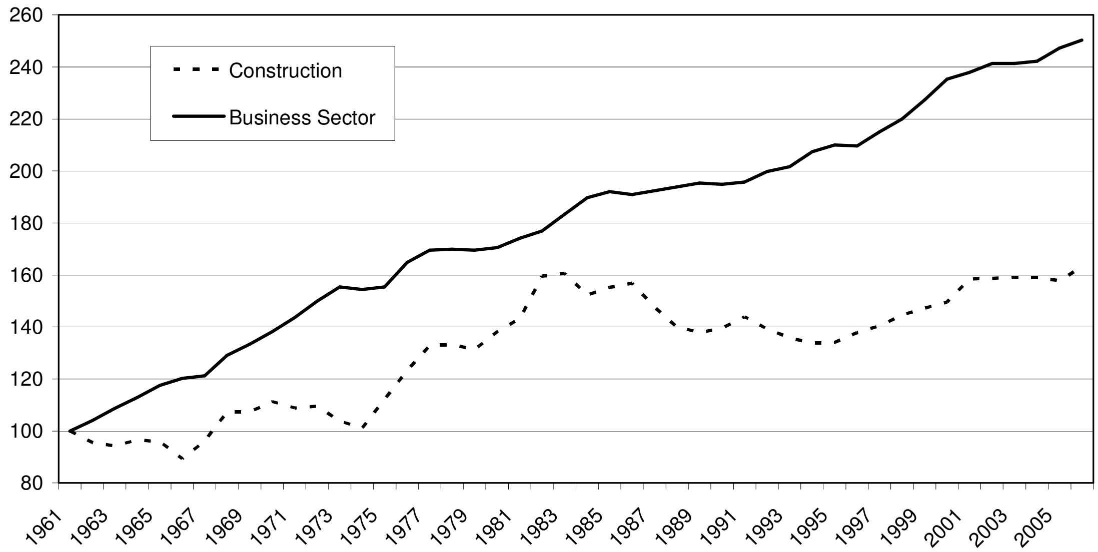
[2] In addition to the charts and summary tables provided in this paper, Appendix tables provide additional information. Appendix IV provides a list of these tables. The tables can also be accessed at http://www.csls.ca/reports/csls2007-01-Tables.pdf

[3] The business sector is the for-profit business component of the economy.

Chart 4: Index of labour productivity (output per hour), construction industry and business sector, Canada, 1961-2006

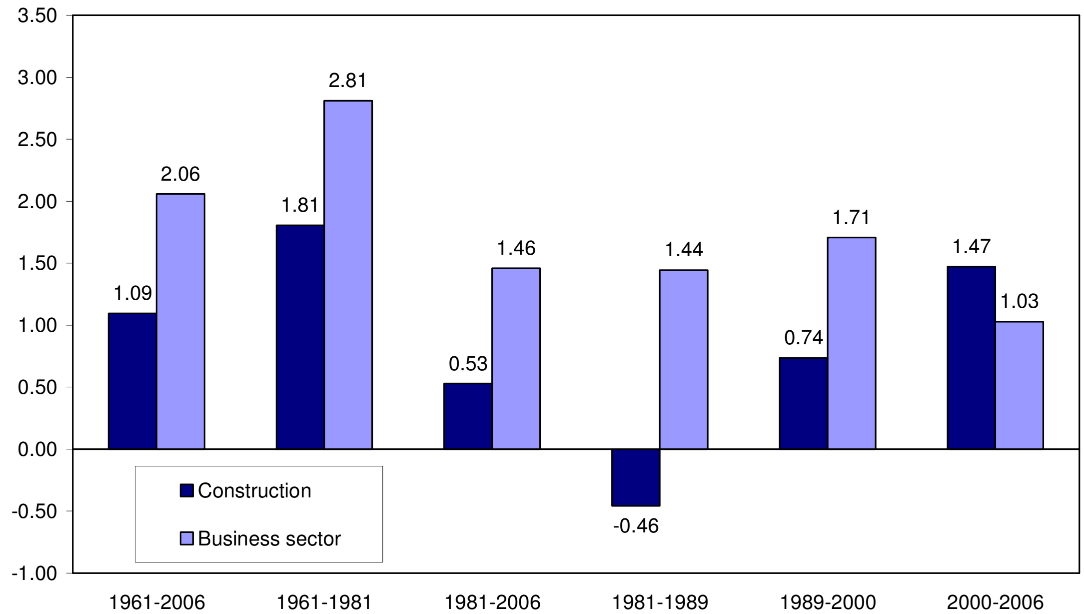


Source: Calculated by CSLS from Statistics Canada Productivity Measures.

The underperformance of the construction industry relative to the business sector total has been consistent across cyclically neutral time periods,[4] but the gap between productivity growth rates has varied (Chart 5). Overall, between 1961 and 2006 construction industry productivity grew at a compound annual rate of 1.09 per cent, compared to 2.06 per cent in the business sector as a whole. In the earliest period, between 1961 and 1981, construction industry output per hour advanced at a rapid 1.81 per cent per year, and total business sector productivity also grew quickly at 2.81 per cent per year. Between 1981-2006 productivity in the construction industry grew at only 0.53 per cent per year, while total business sector productivity advanced at a much more robust 1.46 per cent per year.

[4] Cyclically neutral time periods on a peak-to-peak basis: 1961-1981 (two cycles), 1981-1989, and 1989-2000. The 2000-2006 period is not a cyclically neutral period, since there has not been a peak since 2000.

Chart 5: Labour Productivity (output per hour) growth trends, construction industry and business sector, Canada, 1961-2006



Source: Calculated by CSLS from Statistics Canada Productivity Measures.

When this lengthy period is decomposed into shorter periods, we can see that construction productivity is much more variable than business sector productivity. Between 1981 and 1989, productivity in the construction industry actually declined by 0.46 per cent per year, whereas business sector productivity grew at 1.44 per cent per year. From 1989 to 2000 construction industry productivity growth improved over the previous period to an average annual rate of 0.79 per cent, but still could not match the business sector productivity growth rate of 1.72 per cent per year. In the most recent six-year period, 2000-2006 construction industry productivity exhibited its best performance relative to the overall business sector, albeit because business sector productivity growth slowed to only 1.03 per cent per year and construction industry productivity remained comparatively stable, increasing by 0.63 points, to 1.47 per cent per year.

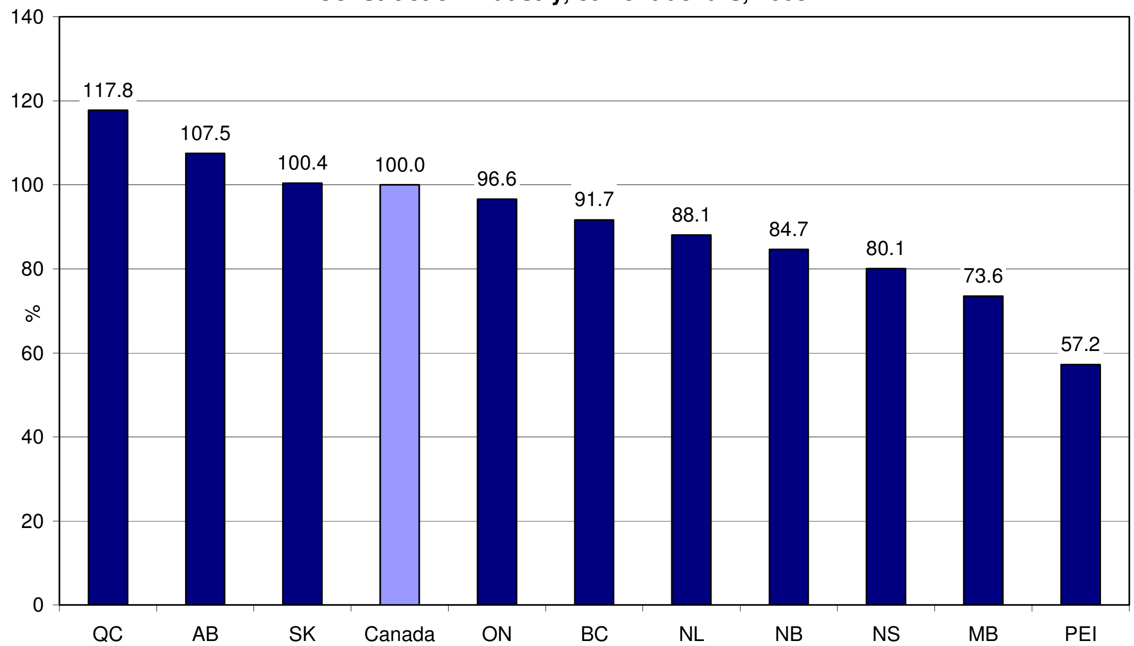
Construction Labour Productivity Trends by Province

While current dollar GDP per hour worked in the construction industry in 2003 in Canada as a whole was $33.03, this performance masked wide variations in construction productivity among the provinces (Chart 6).[5] Quebec showed by far the highest productivity with a value of per hour output of $39.91 (117.8 per cent of the national average), while the lowest productivity was observed in Prince Edward Island, at $18.89

[5] Data on output per hour by province is in terms of value productivity, not in terms of physical productivity, since estimates of purchasing power parity prices for the construction industry across provinces are not available.

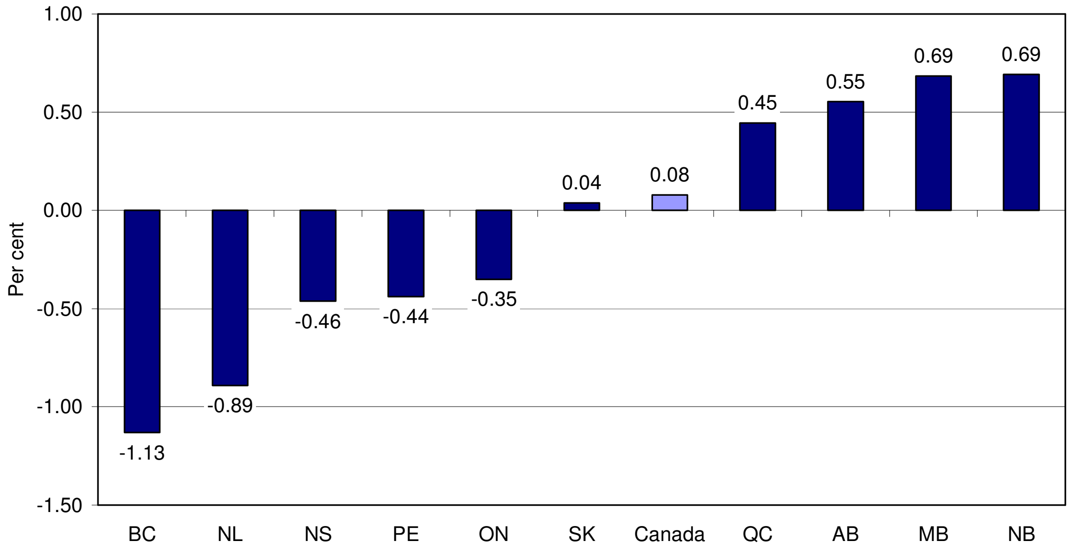
(57.2 per cent of the national average). Alberta showed the second highest level of productivity, while Manitoba and Nova Scotia had relatively low levels of productivity. The other provinces fell somewhere in between, most approximately between $28.00 and $33.00 of output per hour.

Chart 6: Labour productivity by province as a percentage of Canada's labour productivity in Construction Industry, current dollars, 2003



Source: Calculated by CSLS from Statistics Canada CANSIM II table 379-0025 and 383-0010.

Chart 7: Labour productivity (real GDP per hour) growth, 1987-2005, per cent



Source: CSLS Database: Labour, Capital and Total Factor Productivity by Industry for Canada and the 10 provinces: http://www.csls.ca/data.asp. Tables S1 and S7.

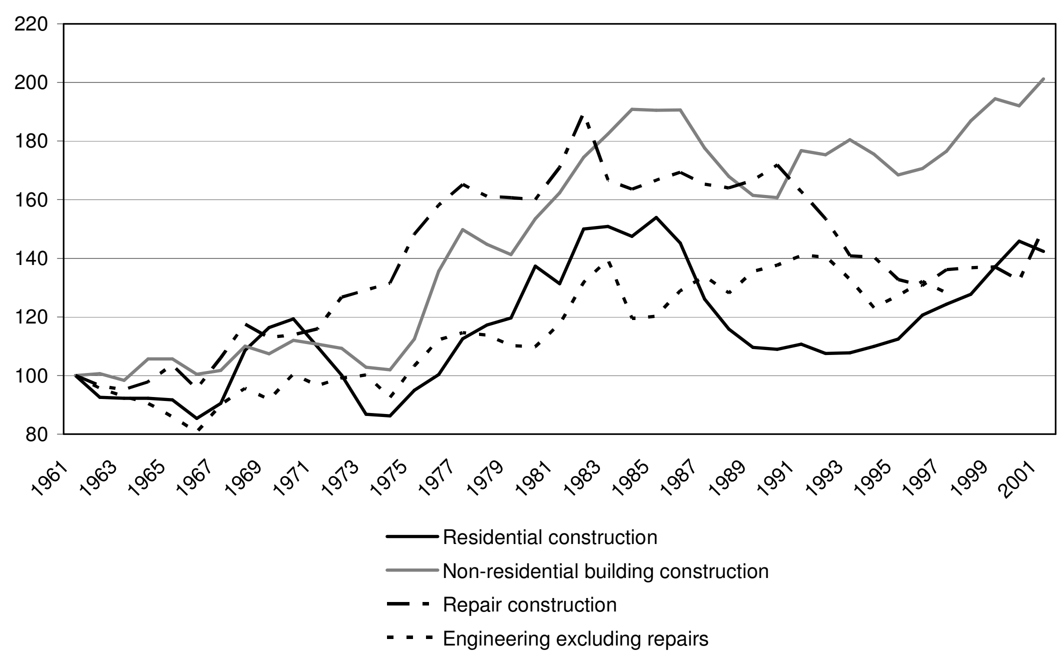
Turning to growth rates in constant dollar GDP per hour worked, on a provincial basis, the diversity across provinces is even more pronounced than in levels (Chart 7). In the 1987-2005 period, construction industry productivity in Canada rose at a compound annual rate of 0.08 per cent. Five provinces exhibited negative growth rates over the period, while five showed positive growth rates. The poorest performers were British Columbia (-1.13 per cent) and Newfoundland (-0.89 per cent). Nova Scotia (-0.46 per cent), Prince Edward Island (-0.44 per cent) and Ontario (-0.35 per cent) all showed slightly negative growth rates. The highest compound annual growth rate (0.69 per cent) was observed in New Brunswick and Manitoba, with Alberta (0.55 per cent), Quebec (0.45 per cent) and Saskatchewan (0.04 per cent) also showing positive productivity growth.

Labour Productivity Trends by Construction Sub-Industry

Turning to trends in the key construction sub-industries, it is clear that some sub-industries have exhibited a better productivity performance than others (Chart 8). Unfortunately, data at the sub-industry level are not available for the most recent years. In the case of engineering construction excluding repairs, the data are only available to 1997. Non-residential building construction was the outstanding performer. Rising to more than twice its 1961 level of productivity in 2001. All construction sub-industries saw productivity fall in the recession of the early 1990s, but only non-residential building has since exceeded its pre-recession peak. Residential construction enjoyed strong productivity growth from 1975 to 1986, then productivity slumped until 1993. Residential construction productivity increased steadily from 1994 to 2000. Repair construction productivity peaked in 1982 then fell significantly until 2000. Finally, productivity in engineering construction excluding repairs made slow but steady progress from 1966 to 1993, then suffered a reversal.

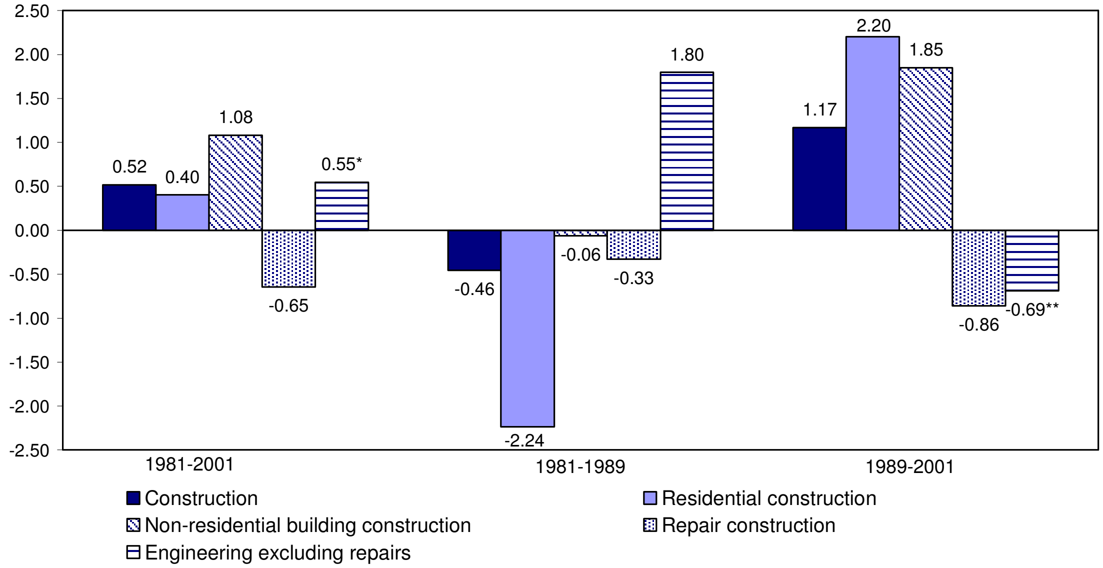
Again turning to growth rates, the mixed performance of construction sub-industries is quite noticeable (Chart 9). Overall between 1981 and 2001 construction productivity grew at a compound annual rate of 0.52 per cent. Residential construction exhibited 0.40 per cent growth. As mentioned above, non-residential construction considerably outperformed the other sub-industries in this period, showing a compound annual rate of productivity growth of 1.08 per cent. Repair construction was the least successful sub-industry in terms of productivity growth in this period, declining 0.65 per cent per year on average. Over 1981-1997, since the series terminated in 1997, engineering construction excluding repairs increased at 0.55 per cent per year. Between 1981 and 1989 all sub-industries showed negative productivity growth rates except engineering construction excluding repairs, which managed a brisk increase of 1.80 per cent per year. Productivity in overall construction, residential construction, non-residential building construction and repair construction declined at average annual rates of 0.46, 2.24, 0.06 and 0.33 per cent respectively. The 1989 to 2001 period saw much better annual productivity growth than the 1980s. Overall construction productivity grew at 1.17 per cent per year. Residential construction almost made up the losses of the 1980s and grew at 2.20 per cent per year, and non-residential building advanced at a healthy 1.85 per cent. Repair construction and engineering construction excluding repairs (1989-1997), on the other hand, saw productivity declines at 0.86 per cent and 0.69 per cent per year respectively.

Chart 8: Indexes of labour productivity, construction sub-industries, (1961 = 100), 1961-2001



Source: Appendix Table 8.

Chart 9: Output per hour trends, construction industry and component sub-industries, Canada, 1981-2001

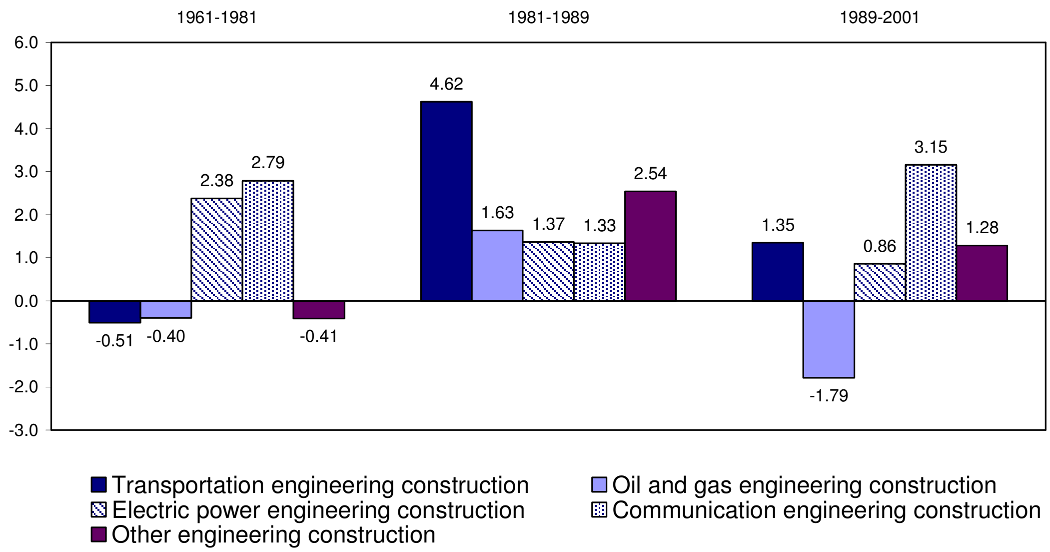


Source: Appendix Table 8.
Note: There are four components in construction sector: residential construction, non-residential building construction, repair construction and engineering construction excluding repairs. Data for engineering construction excluding repairs are not available for 1997-2001. * 1981-1997; ** 1989-1997

Engineering construction encompasses a wide variety of activities. As a result, it is informative to examine in more detail the performance of the engineering construction sub-industry (Chart 10).

- In the twenty years between 1961 and 1981, communication and electric power engineering construction showed positive productivity growth, at 2.79 and 2.38 per cent per year. Transportation, oil and gas, and other engineering construction all posted negative productivity growth rates of 0.51, 0.40, and 0.41 per cent per year respectively.
- Between 1981 and 1989 engineering construction improved its productivity performance. Transportation, oil and gas, communication, electric power and other engineering construction grew at 4.62, 1.63, 1.37, 1.33 and 2.54 per cent per year respectively.
- Finally, between 1989-2001 only oil and gas engineering construction showed a negative productivity growth rate of 1.79 per cent per year, while communication engineering construction had outstanding productivity growth of 3.15 per cent per year. Transportation, electric power and other engineering construction productivity grew at moderate rates of 1.35, 0.86, and 1.28 per cent per year respectively.

Chart 10: Output per hour trends in components of engineering excluding repairs in Canada, 1961-2001



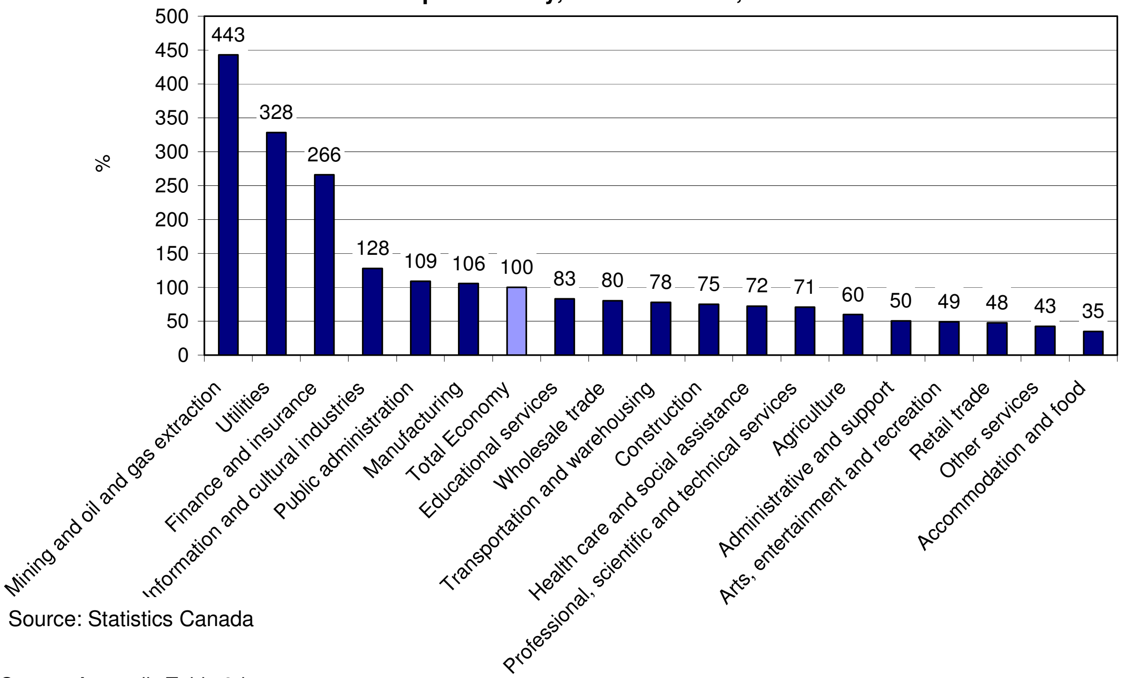
Source: Appendix Table 8.

Comparison of Labour Productivity Levels – Discussion of Trends by Industry

Labour productivity levels can be calculated using estimates of hours from the Statistics Canada productivity program and gross domestic product at basic prices estimates. For this cross-industry and a cross-provincial analysis, current-dollar data are used to avoid the distortion due to relative price changes embedded in constant dollars estimates.

Based on 2003 estimates, labour productivity in Canada averaged $43.97 per hour. The construction industry at $33.03 per hour ranked eleventh among the 18 industries identified in the North American Industry Classification System (NAICS). Chart 10a shows labour productivity for all NAICS industries as a percentage of the total economy labour productivity. Construction (75 per cent) ranks fourth among the goods-producing industries, ahead of agriculture (60 per cent), but lagging manufacturing (106 per cent). Because of its high level of capital intensity, the mining, oil and gas (443 per cent) and the utilities (328 per cent) industries both had very high levels of labour productivity compared to the industrial average. Among the 13 service industries, only finance and insurance (266 per cent), information and cultural industries (128 per cent) and public administration (109 per cent) had labour productivity levels above the industrial average.

Chart 10a: Labour productivity by industry as a percentage of total economy labour productivity, current dollars, 2003



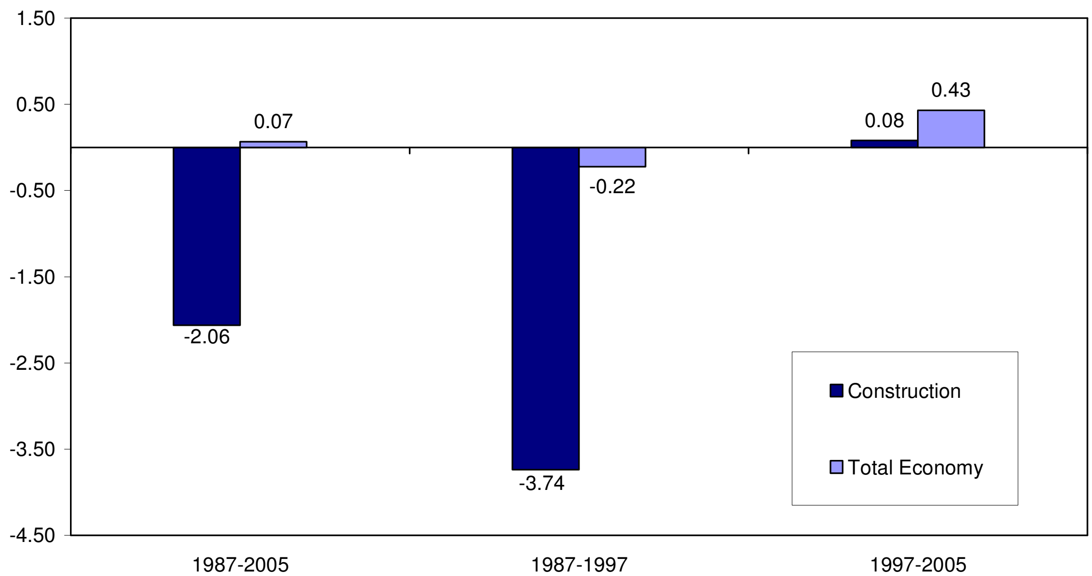
Source: Appendix Table 8d.

Construction Capital and Total Factor Productivity Trends

Although not the primary focus of this study, it is also informative to examine trends in capital productivity (Chart 11). Construction industry capital productivity growth has tended to grow in the opposite direction from total economy capital productivity. Between 1987 and 2005, construction industry capital productivity declined at an average annual rate of 2.06 per cent, while total economy capital productivity grew at a slightly positive 0.07 per cent per year. Over the ten years 1987-1997, construction industry capital productivity declined at 3.74 per cent per year, while total economy capital productivity only declined at 0.22 per cent per year. Between 1997 and 2005 construction industry capital productivity slightly increased at 0.08 per cent per year, while total economy capital productivity grew at 0.43 per cent per year.

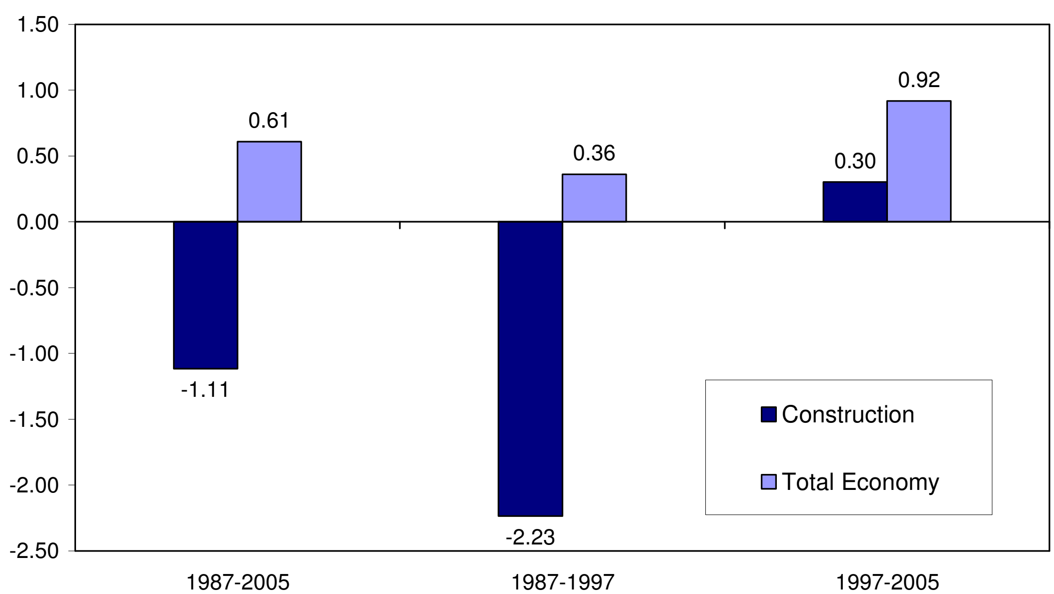
Finally, total factor productivity (TFP) provides a broad picture of productivity, taking into account both labour and non-labour inputs (Chart 12). See Part IV for a more detailed explanation. As was the case with capital productivity, TFP growth in the construction industry tended to go in the opposite direction of total economy TFP growth. Between 1987 and 2005 total economy TFP growth was 0.61 per cent per year, whereas in the construction industry TFP declined at 1.11 per cent per year. Turning to sub-periods, between 1987 and 1997, construction industry TFP declined at 2.23 per cent per year, while total economy TFP grew at 0.36 per cent per year. In the sub-period from 1997 to 2005, TFP in the construction industry increased at a rate of 0.30 per cent, while total economy productivity growth advanced at 0.92 per cent per year.

Chart 11: Output per $1000 capital stock trend in construction and total economy in Canada (CSLS database based)



Source: CSLS Database: Labour, Capital and Total Factor Productivity by Industry for Canada and the 10 provinces: http://www.csls.ca/data.asp.

Chart 12: Total factor productivity trends, construction industry and total economy, Canada



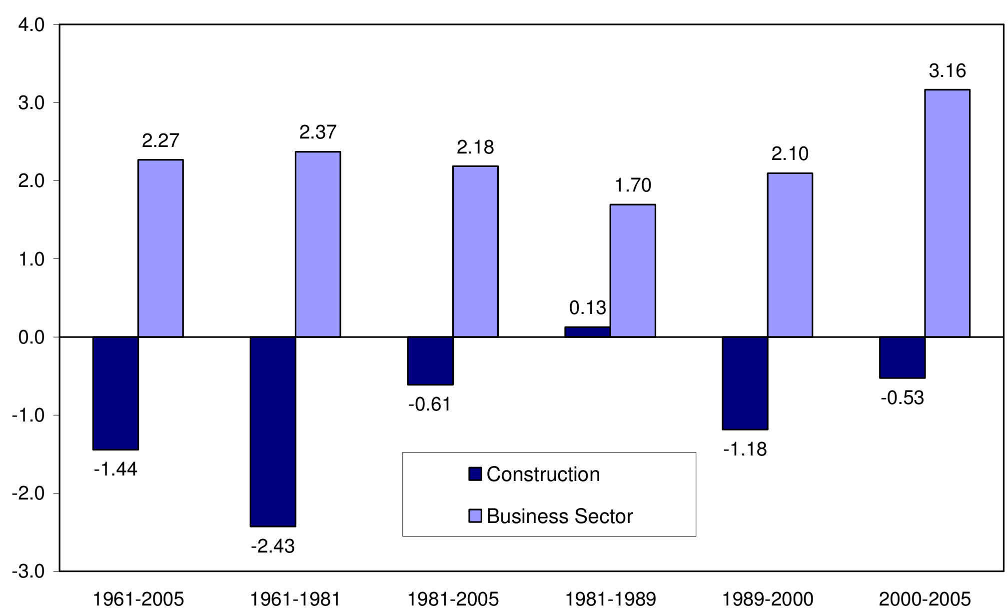
Source: CSLS Database: Labour, Capital and Total Factor Productivity by Industry for Canada and the 10 provinces: http://www.csls.ca/data.asp.

Construction Industry Productivity Trends in the United States

This section explores productivity trends in the construction industry in the United States. Unlike in Canada, there are no official estimates of construction productivity in the United States. The Centre for the Study of Living Standards has compiled construction industry productivity trends for the United States, based on estimates of real output and total hours worked by industry at the national level from 1961 to 2005. Data are from the Bureau of Economic Analysis (BEA) National Economic Accounts and Industry Economic Accounts.

Over the entire 44-year period, 1961-2005, productivity in the construction industry declined at 1.44 per year, while productivity in the business sector overall grew at 2.27 per cent per year (Chart 13). In the first two decades of the period, 1961-1981, the productivity decrease in the construction industry at 2.43 per cent per year, was far behind productivity growth in the business sector overall, which grew at 2.37 per cent per year. In the next 24-year period, 1981-2005, construction industry productivity growth still declined, at 0.61 per cent, while business sector productivity growth continued at only a slightly reduced rate of 2.18 per cent. When the 1981-2005 period is decomposed, interesting variations in productivity growth rates become apparent. From 1981 to 1989 construction industry productivity actually had a positive growth of 0.13 per cent but was well below business sector productivity growth of 1.70 per cent per year. However, in the 1990s and 2000-2005 period, construction productivity growth ceased; it declined 1.18 per cent per year in the 1990s and 0.53 per cent per year from the 2000 to 2005. At the same time business sector productivity growth accelerated, from 2.10 per cent per year in the 1990s to 3.16 per cent per year in the period from 2000 to 2005.

Chart 13: Labour productivity (output per hour) trends, construction industry and business sector, United States, 1961-2005 (BEA NIPA based)



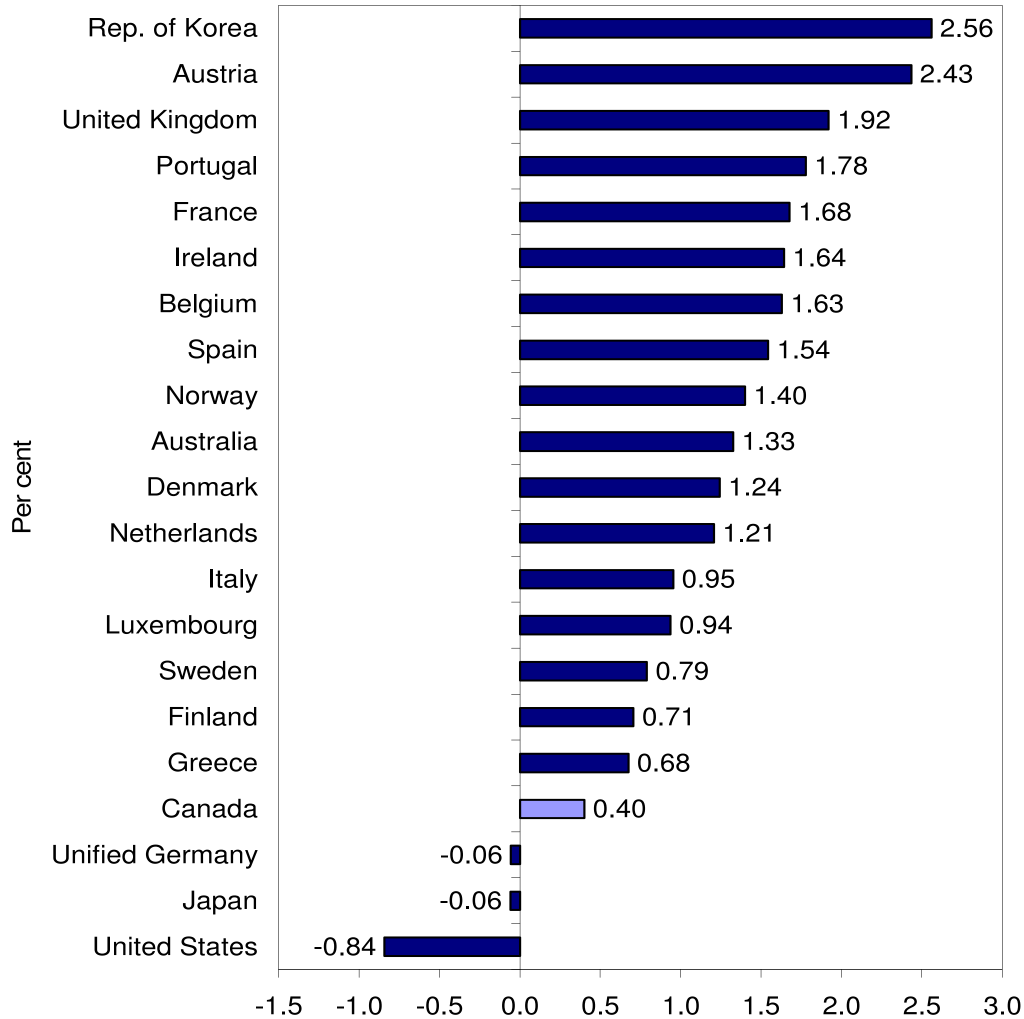
Source: Appendix Table 19.

Construction Industry Productivity Trends Internationally

This section examines trends in productivity growth across countries for which data are available. Data for this section are drawn from the Groningen Growth and Development Centre, 60-Industry Database.[6] This source is used since the data are classified according to the International Standard Industrial Classification (ISIC), which makes industries comparable across countries.

[6] Current as of June 2006 and available at http://www.ggdc.net.

Chart 14: Labour productivity growth rates, construction Industry, 1979-2003



Source: Harrison (2007:Appendix Table 3).
Note: -Average annual growth rates for countries without data available for 2003, such as Japan, Korea and Norway, are calculated for the period 1979-2002
-Construction sector is defined according to the International Standard Industrial Classification (ISIC-rev.3.) category 45.

Over the period 1979-2003, the growth rate of labour productivity varied greatly across countries (Chart 14). The United States showed the poorest productivity growth in this period, with an average annual decline of 0.84 per cent per year. The best performance was that of the Republic of Korea, which saw productivity growth of 2.56 per cent per year. Other countries that experienced productivity declines in construction between 1979 and 2003 were Japan and Germany. Strong productivity performers included Austria (2.43 per cent), the United Kingdom (1.92 per cent), and Portugal (1.78 per cent). Canada's construction industry productivity growth performance of 0.40 per cent per year was fourth from the bottom.

Several observations made in this part have implications for the analysis of construction industry productivity measurement in Canada. The international comparison (Chart 14) shows that there have been long-term differences in the measured productivity growth rates in the construction industry across countries. On the other hand, some of the evidence presented in this Part suggests that measurement may not be an important factor in the performance of the construction industry in Canada. Given that Statistics Canada does not apply different methodologies of productivity measurement to different provinces, the inter-provincial variations in productivity growth rates suggest that other factors are contributing to the productivity performance of the industry. With the average productivity growth rate in the construction industry in New Brunswick at 0.69 per cent and that of British Columbia at -1.13 per cent, other factors must be more important than measurement in explaining this divergence.

Part II: Review of the Literature on Measurement Issues in Construction Industry Productivity

The purpose of this review is to assess the current state of knowledge about measurement issues related to construction industry productivity. As discussed in detail in Part IV, there are several issues that make measuring productivity in the construction industry a more complicated and difficult task than the measurement of productivity in most other industries. For this reason, researchers have long understood that measurement problems are likely to exist, and research on the topic has been underway, albeit interspersed with many years of inactivity, since the 1950s.

From a Canadian perspective, it is unfortunate that almost all of the research on this important issue has been undertaken in the United States. With the exception of three papers published by Statistics Canada in 1994 (Mohammadian and Seymour, 1994) and 1997 (Mohammadian and Seymour, 1997; Mohammadian and Waugh, 1997), some research by John O'Grady and Greg Lambert on underground activity in the construction sector in Ontario (O'Grady and Lambert, 1998), and a study by the Centre for the Study of Living Standards (CSLS) for the Canadian Mortgage and Housing Corporation (CSLS, 2001), there has not been any research effort directed towards construction productivity measurement issues in Canada. As a result, this review must predominantly focus on research conducted in the United States. For the most part, the general measurement issues discussed in the US literature are relevant for Canada. However, because there are major differences between Canada and the United States in the methods used to compile productivity estimates, the US literature is sometimes less relevant to the Canadian context.

This part is composed of two sections. The first looks at the US literature on biases in construction price indexes. The second section reviews the Canadian literature on construction industry productivity. Both sections are organized chronologically.

Biases in Construction Price Indexes, US Literature

Early Literature, 1965-1981

Early literature in the United States focused on the possibilities of bias in the price series used to deflate nominal output in the construction industry. This issue remains one of the most important in construction productivity measurement. Writing in 1965, Douglas C. Dacy stated the essential paradox that continues to exist in the industry to this day:

> Anyone who observes the construction process for new commercial buildings or, better still, highways, must be puzzled by these relatively low productivity figures. Likewise, it is difficult to reconcile the numerous trade journal articles on technological advances in construction with the opinion that the industry is backward. No purpose is served by

> commenting on the published estimates, which are, in any event, too sketchy. (Dacy, 1965: 407)

It was this divergence between the story told by construction industry practitioners and observers, and the story told by the official statistics, that led to much of the interest in this topic. The same divergence continues to drive interest in the topic today. Dacy went on to conclude that the index used to measure construction prices had greatly overstated the rise in prices, "with the attendant effect that every economist who has dealt with construction as a sector has understated productivity." (Dacy, 1965: 411)

Dacy's conclusion was based on the fact that the US Department of Commerce had been using a cost index to deflate construction output. A cost index is a weighted average of labour and non-labour inputs. If input prices rise faster than output prices, because of rising productivity and falling unit costs or narrowing profit margins, for instance, and input prices are used to deflate output, then output will be over-deflated, and the increase in real output, and therefore productivity, will be understated.

Building on the work of Dacy, Gordon (1968) proposed a new price index for construction output, which he argued suffered from fewer defects than the official Department of Commerce deflator used at the time. Gordon's deflator relied less heavily on input-cost indexes and more on output-price indexes. He concluded that the official deflator had underestimated the growth of construction output by 34 per cent between 1919 and 1965 and 40 per cent between 1948 and 1965 alone. As a result, he concluded that a substantial portion of the productivity improvement in construction had been overlooked. (Gordon, 1968: 423) After the work of Dacy and Gordon, the US Department of Commerce did make some efforts to improve the measurement of construction prices.

Stokes, Allen and Pieper, 1981-1990

In 1981 H. Kemble Stokes sought to explain the divergence between construction sector and total non-farm private sector productivity. Stokes began with the fact that construction productivity had risen 2.4 per cent annually from 1950 to 1968, at which point it had peaked, then declined, from 1968 to 1978 at a rate of 2.8 per cent annually. In contrast, total non-farm private sector productivity had also risen by 2.4 per cent annually from 1950 to 1968, but had then risen by 1.2 per cent annually from 1968 to 1978. While overall productivity growth appeared to have slowed in the 1970s, construction productivity growth plummeted. Stokes looked at seven factors: the measurement of real output, shifts in the composition of construction industry output, changes in capital per worker, demographic changes in the workforce, economies of scale, regional shifts, and changes in work rules or practices. Stokes was only able to conclude that these factors explained a small part of the productivity decline in construction.

With reference to the measurement of real output, Stokes concluded that deflation using input cost indexes overstates the rise in final prices to the extent that productivity increases or profit margins narrow. However, Stokes also concluded that the inappropriate use of input-cost indexes was an inadequate explanation of the construction productivity decline that began in 1968. He reached this conclusion, because in 1963 the United States Census Bureau introduced a construction output price index, which thereafter was used to deflate half of all construction expenditures. Stokes argued that switching to a more price-index-based deflation system should have resulted in more productivity growth showing up in the data. That is, provided there was productivity growth in the construction sector. (Stokes, 1981: 496)

Stokes also identified potential measurement issues surrounding gross output measurement: whether maintenance and repair expenditures were being included and whether appropriate procedures were being used to estimate the value of single-family housing put in place. Stokes could not resolve the issue of possible underestimation of maintenance and repair expenditures owing to a lack of data. The question of the correct estimation methodology being used to estimate the price of housing output put in place focused on whether it was better to use permit values or sales prices. However, Stokes concluded that there did not appear to be any obvious measurement problem, but he did note that increasing use of prefabricated materials led to a situation is which

> the index of construction supplies in the manufacturing sector could be expected to rise more rapidly than either construction industry real value added or real gross output. Productivity, when output is measured by real gross output, as in the Bureau of Labor Statistics studies, could be expected to show a more favourable trend since the increased manufacturing hours to produce the materials and supplies for the construction sector are not included in the calculation. (Stokes, 1981: 497)

Following Stokes, Steven G. Allen (1985) at North Carolina State University produced one of the most important and widely cited articles in the field of construction productivity research. Allen had roughly the same objective as Stokes; he attempted to uncover the sources of the productivity decline in construction from 1968 to 1978. He determined that 41 per cent of the decline could be explained by real factors. The most important factor was the reduction in skilled-labour intensity resulting from a shift in the composition of construction output from large scale commercial, industrial and institution projects, to single-family homes. He identified other important sources of the decline in productivity as declines in the average number of employees per establishment, the capital-labour ratio, the per cent of employees who were unionized, and the average age of the workforce.

While Allen's results emphasizing real factors, not mismeasurement, were encouraging, a considerable portion of the productivity decline remained unexplained. Allen then tried to account for the remaining decline by focusing on the possibility that nominal output was over-deflated. Unlike Stokes, Allen constructed an alternative, and admittedly ad hoc, price index, which accounted for 51 percent of the total decline in construction productivity observed in the statistics produced by the Bureau of Labor Statistics (BLS). Allen made two adjustments to the non-residential construction deflator. First, he replaced the non-residential construction deflator with a price per square foot index, and he used only the urban portion of the Federal Highway Administration price index, assuming that the rural portion was biased upward due to the completion of the interstate highway system in that period. Allen argued that the final phase of the interstate highway system was one of the most difficult and expensive. He then used these deflators as an alternative to the cost-index-based deflators of the Bureau of Economic Analysis (BEA). Like Stokes, Allen also mentioned the possibility that nominal output was being underestimated, but he claimed that there was insufficient evidence to reach any conclusion. Allen claimed that he had explained 92 per cent of the productivity decline in construction between 1968 and 1978; however, it was not long before his results were challenged.

Paul Pieper (1989) claimed that Allen's (1985) explanation of the construction productivity decline was incorrect. Pieper argued that real factors could not account for the construction productivity decline and that Allen's criticisms of the National Accounts construction expenditures deflator were inaccurate and that his proposed adjustments to create an alternative deflator were misleading. (Pieper, 1989: 543) Pieper's first criticism of Allen's mismeasurement argument was that Allen claimed the BEA deflator for construction output was "largely" based on cost-indexes. Like Stokes (1981), Pieper notes that this is not the case, and that only approximately one-quarter of construction expenditures are deflated using cost indexes.

Pieper's second criticism of Allen's mismeasurement argument is that Allen claimed that use of cost indexes would give an upward bias to the construction deflator. Again, as Stokes was careful to note, and as Allen did not, such a bias would only occur if labour productivity in the construction sector were actually rising. Pieper pointed out that if labour productivity had remained constant, a cost-index-based deflator would be unbiased, and that if labour productivity had fallen, such a deflator would have a downward bias. Pieper then goes on to argue that Allen's two adjustments to the BEA deflator, to produce an alternative deflator are based on assumptions that are unsupported by evidence. Pieper concluded that Allen's attempt to explain the construction productivity decline was unsuccessful, because "conventional factors cannot explain the decline while the mismeasurement hypothesis awaits hard evidence." (Pieper, 1989: 546)

Allen (1989) was quick to challenge Pieper's (1989) criticism of his research. But Allen only partially responded to Pieper's criticisms. To the challenge that the BEA deflator was not "largely" a cost index, Allen maintained that on one hand the only price deflators used were for single family homes and highways, which together accounted for only one-third of construction sector output. However, he acknowledged that these deflators were used to deflate the output of other segments of the construction sector. It seems that an important question, which neither Pieper nor Allen addressed, is what consequences for measurement result from the use of a price index from one segment of the construction sector, single family homes, for instance, to deflate the output of a different sector. This question will be pursued in more detail within the Canadian context in Part IV.

In response to Pieper's argument that the assumptions underlying his alternative deflator were unfounded, Allen replied that Pieper had "no evidence that either adjustment was inappropriate." (Allen, 1989: 548) At the same time, Allen did admit that Pieper was correct in pointing out some errors in his original calculations both in the area of real variables and in that of mismeasurement. As a result Allen was forced to concede that his research could only explain 56.5 per cent of the decline in construction sector productivity, and not the 92 per cent he had originally claimed. (Allen, 1989: 549)

Lack of Progress and New Directions, 1990-2006

After the Allen-Pieper controversy, the debate about the causes of the construction productivity decline, as observed in the statistics, was very much open again. Pieper (1990) surveyed the state of research on construction productivity and looked ahead to future avenues of research that he felt would be fruitful to pursue. He concluded that because the BEA continued to use cost indexes, except in the case of the highways and single-family homes, and it seemed likely that the BEA deflator for new construction had a significant upward bias between 1963 and 1982. (Pieper, 1990: 260) He also made two important remarks, both of which are as relevant today as they were when written:

> first, progress in construction deflation has been made in the past when there has been interaction between government statisticians and the academic profession. The harsh criticisms of the Stigler committee and other academics in the sixties led to a demand for better statistics, which spurred changes in deflation by the BEA. Similarly, the profession's lack of interest in the area in the past decade has abetted an inactivity by government. Second, there is probably no single best method for deflating construction. Each method has its strengths and weaknesses, the relative amounts of which will vary by the type of construction. With a few minor exceptions, the estimation approach has not been used in the past because it is not based on transaction prices. However, given the heterogeneity of many types of construction, it appears that some types of estimation indexes are necessary if reliance on cost and proxy indexes is to be reduced. (Pieper, 1990: 260)

Ironically, given Pieper's argument for more research effort, following his survey there was again a hiatus in research on construction productivity in the United States. However, since 2000, seemingly in part out of frustration with the unwillingness or inability of the Bureau of Labor Statistics (BLS) to even produce construction sector productivity statistics, the construction industry in the United States has begun to pursue its own initiatives to measure productivity. The BLS claims that it does not have suitable data to produce construction productivity estimates (Allmon, *et al.,* 2000: 97) and that it "does not currently have plans to develop productivity measures for the construction industries in the near future." (Building Futures Council, 2005: 9) This frustration can be seen indirectly in the pessimistic conclusion of a recent article that asserted that given the current state of the statistics used to compute productivity estimates in the United States, "it cannot be determined if labor productivity has actually increased, decreased or remained constant in the construction industry for the 1979-1998 period." (Rojas and Aramvareekul, 2003: 46)

Not surprisingly, this lack of information about productivity has led construction industry stakeholders in the United States to consider alternatives. The approach taken by the industry to measure productivity is, in a sense, the reverse of the procedures traditionally favoured by those who measure and estimate productivity. The basic concept is known as "activity-level" productivity, and it involves looking at individual construction activities, one-by-one, to determine whether productivity has improved. The most obvious disadvantages to this approach, in comparison with a more traditional aggregate approach, are that a complete picture of the construction industry would require all tasks to be summed up in some way. If that is possible, then there would still remain the possibility that many tasks are being omitted, either because they are not recognized as distinct tasks, or because they are too difficult to measure. This problem may be especially serious in the case of tasks that do not produce an output directly, such as supervision or management. Second, such a method of measuring productivity, if it is to be done well, requires large amounts of high quality data. Such requirements may be prohibitive if the approach were to be implemented on a large scale.

Eric Allmon, Carl T. Haas, John D. Borcherding, and Paul M. Goodrum, all from the University of Texas at Austin, wrote the original paper on activity-level analysis in 2000. The data used in the study were Means' *Building construction cost data,* published by the R.S. Means Co. Inc. from 1960-1997. The authors selected tasks to create a sample with a variety of technological intensities, terms of trade, and sectors. They used benchmarks of unit labour cost and unit output. Costs were deflated using the Consumer Price Index.

For the purposes of comparison with the Means manual data, the authors presented another alternative method for assessing productivity improvement. They looked at direct work rate data from 72 projects in Austin, Texas, between 1975 and 2000. The direct work rate is "the percentage of time spent on productive actions such as erecting formwork, tying reinforcing steel, placing concrete. Other work activities such as transporting materials and tools or getting instructions are considered support time." (Allmon, *et al.*, 2000: 98) Idle time is when the workforce is not working, for example, while taking a break. The authors acknowledge that direct work rates are not necessarily correlated with productivity since it is possible to hold direct work rates constant and increase product by increasing the skill level workers or the capital equipment that they have to work with. Nonetheless, they believe direct work rates can be useful in assessing productivity, and that increasing direct work rates "usually" increases productivity. (Allmon *et al.*, 2000: 102) Data show that direct work rates have not shown a trend increase or decrease in Austin, and the authors claim that Austin is fairly typical of other building markets in the United States, but they do not provide evidence for such an assertion. Allmon *et al.* (2000) conclude that construction productivity appeared to have increased substantially.

Following from research on activity-level construction productivity, in 2002, Paul Goodrum, Robert Glover, and Carl Haas, looked specifically at possible explanations for the divergence in aggregate and activity estimates of US construction productivity.

Incidentally, this issue was the same one that Dacy had set out to explore in 1965. The authors identified three measurement issues that could contribute to explaining the divergence: proxy indexes, potential bias in the Census Single-Family Houses Under Construction Index, and offsite production.

First, they touch on the issue of the use of proxy indexes to deflate construction expenditures. They note that the US Census Bureau Single-Family Houses Under Construction index, which is designed to deflate nominal output in the residential construction sector, is also used to deflate nominal output in the non-residential and military construction sectors. The result is that more than half of the Census Value of Construction Put in Place (the measure of output in the construction sector used in the compilation of productivity estimates) is deflated using this index. The authors contend that this procedure is problematic because

> there have been significant breakthroughs in the means and methods of non-residential and military construction, including modularization, prefabrication, information technology, and construction automation. These breakthroughs have not occurred in residential construction. Furthermore, significant fluctuations in new house prices have occurred as a result of interest rate changes. Therefore, the use of the Single-Family House Under Construction index in non-residential and military construction sectors will adversely effect their output measurement. (Goodrum *et al.,* 2002: 416)

While interesting hypotheses the authors do not offer any evidence to support them.

In the second measurement issue Goodrum *et al.* (2002) identify, they also reiterate Pieper's criticism of the Census Single-Family Houses Under Construction Index on the grounds that it ignores changes in the quality of construction. They note, as did Pieper, that if the index is biased, then given that it deflates more than half of construction sector output, there is reason to believe that both real output and productivity are underestimated.

Finally, citing Haas *et al.* (2000) Goodrum *et al.* (2002) select a growing trend to offsite production, which is impacting construction sector productivity, as the third measurement issue. The essential point is that many firms who construct prefabricated units are classified as manufacturing establishments, and therefore are not included in the construction sector for the purposes of productivity measurement. Haas *et al.* (1999) indicated that between 1984 and 1999 prefabrication and preassembly as a percentage of industrial project work increased from 14 to 27 per cent. This evidence was, however, based on 29 surveys of construction industry practitioners, who were asked to recall the percentage of project work that was done in the form of prefabrication and preassembly. As a result of the small sample and reliance on the perceptions of practitioners, it seems that these figures can at best be seen as suggestive of a trend towards more prefabrication and preassembly in industrial construction. Goodrum *et al.* (2002: 418) point out that there is an issue of how the man-hours and output of firms involved in prefabricating units should be included in estimates of construction productivity.

Goodrum *et al.* (2002) go on to describe the methodology of activity-level analysis and note that it has three principal advantages over the traditional aggregate analysis in the estimation of productivity. First, the issue of price indexes is avoided, because output is measured in real terms, for example cubic meters of concrete placed. Second, for the measurement of activity-level labour productivity, input is measured in terms of labour hours, therefore also eliminating the need to use cost-index-based deflators. Finally, depending on the activity remaining constant, for example, installation of aluminium strip siding, it is easier to compare input and output changes over time. (Goodrum *et al.*, 2002: 418)

The sources for the Goodrum *et al.* (2002) study were cost estimation manuals, often used by construction industry professionals in order to estimate the cost of a project. The researchers selected tasks that appeared in both 1976 and 1998, that had undergone a diverse range of technical changes, and that covered as wide a range of activities as possible. The authors did acknowledge a possible impact of the periodization (1976-1998) (Goodrum *et al.,* 2002: 419), but did not offer alternative periodizations. Another potential source of error in the activity-level methodology is the sensitivity to the cost estimation manual being used. For labour productivity, one manual revealed a 0.8 per cent compound annual growth rate, while the rate was 1.2 per cent and 1.8 per cent based on the other two manuals considered. In the case of multifactor productivity, two of the manuals showed a compound annual growth rate of 0.7 per cent, while the other showed 2.9 per cent. (Goodrum *et al.*, 2002: 420)

Goodrum *et al.* (2002) selected 200 activities and estimated an average productivity improvement of 30.9 per cent between 1976 and 1998, with a 95 per cent confidence interval of +/- 9.2 per cent, resulting in an annual compound growth rate of 1.2 per cent productivity improvement. For the same 200 activities they estimated a mean improvement in multifactor productivity of 36.2 per cent, with a 95 per cent confidence interval of +/- 10.8 per cent, resulting in an annual compound growth rate of 1.4 per cent. (Goodrum *et al.,* 2002: 419) Within the construction industry, the authors noted that certain activities had experienced greater productivity improvement than others. Leading the way was sitework, which experienced the greatest improvement in both labour and multifactor productivity. At the other end of the spectrum, electrical, moisture and thermal protection, and woods and plastic activities experienced the smallest estimated improvements in labour and multifactor productivity. (Goodrum *et al.,* 2002: 420) Overall the study estimated that productivity had on average improved, but had declined in 30 activities, remained unchanged in 63, and improved in 107. A similar pattern was estimated for multifactor productivity.

By way of offering further support to their proposition that activity level productivity in construction has increased, Paul Goodrum and Carl Haas (2002) investigated whether equipment technology could explain some of the improvement. By use of regression analysis they concluded that activities that experienced a significant change in equipment technology also had greater improvement in long-term partial factor productivity than activities that did not experience a change.

The latest research in the United States on productivity in the construction industry focuses on establishing a common set of productivity metrics and definitions for construction companies to use to track productivity. (Park *et al.*, 2005) Like other papers published in the United States since 2000, this research is taking place outside of the BLS, and it takes a bottom-up or activity-level approach to productivity measurement. The outcome of this research initiative is the Construction Productivity Metrics System (CPMS), which comprises 56 data elements grouped into seven major categories. The input of 73 experts was used in selecting and defining the 56 data elements. While insufficient data has been collected to date, the authors believe that the CMPS is a "reasonable productivity data collection tool and when sufficient data are available should be capable of producing reasonable industry benchmarks." (Park *et al.*, 2005: 772)

Biases in Construction Price Indexes, Canadian Literature

Statistics Canada Research Related to Construction Industry Productivity Measurement Issues

Statistics Canada has only published two studies dealing with construction sector productivity measurement. Both *An Analysis of Some Construction Price Index Methodologies* by Mohammadian and Seymour (1997) and *Productivity Adjustment in Construction Price Indexes* by Mohammadian and Waugh (1997) focus on price indexes used in the construction industry.

The former is quite descriptive and general, although it does provide some useful background on Statistics Canada's methodologies. It discusses different types of construction price indexes that are "either being produced or are under consideration" (Mohammadian and Seymour, 1997: 2) at Statistics Canada. These include input cost indexes, output price indexes, and implicit price indexes. Beyond describing the different price indexes, the paper attempts to offer an assessment as to which indexes are more appropriate in different situations and the advantages and disadvantages of each.

On the subject of input cost indexes, Mohammadian and Seymour urge caution in their application. Noting that such indexes are often produced in the trade publications, the authors state that "the adequacy of statistical procedure used in the derivation of these indexes, their sources for prices and the consistent use of these sources to obtain comparably specified observations, may not always be known and therefore should be used with caution." (Mohammadian and Seymour, 1997: 2) An interesting point made by Mohammadian and Seymour is that in the short run, output price indexes tend to be more volatile than input cost indexes since they also include profit margins, which are subject to local supply and demand conditions. (Mohammadian and Seymour, 1997: 6)

Mohammadian and Waugh (1997) had two objectives: to review the available construction productivity estimates in Canada and to investigate alternative approaches to the implicit methods currently used to compile output price indexes for some sectors of the construction industry. Mohammadian and Waugh note that price indexes produced by Statistics Canada for various segments of the construction industry are either input-cost or output-price type indexes. The input-cost indexes are based on composite indexes of wage rates and material prices, which are not adjusted for changes in productivity and gross profit margins. Their use of an input-cost index assumes that changes in wage rates and materials prices result in one-for-one changes in the final product price. They note that Statistics Canada output-price indexes are constructed using the model pricing technique.

Mohammadian and Waugh (1997) suggest that the use of input-cost indexes could be improved if they could be adjusted for labour productivity growth. They suggest a method based on the work of Dacy and then compute an "input-productivity" index for the non-residential construction sector. The input cost index as computed by Statistics Canada is a weighted average of a wage rate index and a materials price index. The input productivity index is constructed by dividing the wage rate index by an index of labour productivity, such that when labour productivity increases, the total input-productivity index falls. The authors argue that the input-productivity index has great potential, because it does not require data on the value of output, person-hours of labour, or the wage rate.

They then compare the input-cost, input-productivity and output-price indexes for non-residential construction and find that the indexes increased at an average annual rate of 3.73, 3.59 and 3.13 per cent respectively. This finding illustrates well the traditional finding that input-cost indexes tend to overstate price increases in construction, in this case by 0.6 percentage points. Furthermore it illustrates the impact that productivity change can have on input-cost indexes. (Mohammadian and Waugh, 1997: 8) Given that their input-productivity appears to more closely approximate the output price index than the input-cost index did, the authors suggest that an input-productivity index

> could therefore be employed in those sectors of the construction industry for which only implicit adjustments are currently possible. Specifically, the mechanical and electrical trade indexes which are currently obtained by using an input cost approach, could be adjusted for productivity by using a similar approach. (Mohammadian and Waugh, 1997: 9)

The authors acknowledge that these results are preliminary and that further research is required to verify and expand its application. Since they only applied the method to one segment of the construction industry (non-residential building construction), future studies could focus on proving that input-productivity indexes are indeed a closer approximation to output-price indexes across many segments of the construction industry. Such a task is difficult, especially given that those segments that currently lack an output-price index and must rely on input-cost indexes would not have a benchmark with which to compare the performance of an input-productivity index. Nonetheless, the approach would seem to warrant further study.

Since the work done by Mohammadian and Seymour (1997) and Mohammadian and Waugh (1997), Statistics Canada has not released any further publications even peripherally related to construction sector productivity measurement. This situation is surprising given that the two papers seemed to indicate a renewed interest in these issues within Statistics Canada and provided suggestions on directions for improvement of productivity statistics in the construction industry.

Construction Productivity Measurement and the Underground Economy in Canada

The introduction of the GST in 1991 gave consumers and producers engaged in construction activities an additional incentive to fail to report or underreport income. Many observers believe that this situation has fuelled the growth of underground activities in the sector, with implications for measured productivity growth. Of course, if both employment and income are underreported in the same proportion, productivity is unaffected. But most observers believe undercoverage is much greater for income than employment, as persons have much greater incentive to underreport their income when filing tax returns than to underreport hours worked when responding to the Labour Force Survey.

If a growing proportion of construction activity is taking place underground and is not reported to the authorities, a growing gap between actual and measured labour productivity growth may emerge, assuming labour input is accurately captured. In theory, such a development could explain some of the weak productivity performance as measured by Statistics Canada in the construction sector in Canada in the 1990s.

According to the Canadian Home Builders' Association (2000b), since the introduction of the GST in 1991, the underground share of total housing activity has increased significantly. A study for the Ontario Construction Secretariat (O'Grady *et al*., 1998) found a large underground economy in the construction sector. It estimated that underground construction employment in Ontario averaged between 58,000 and 79,000 annually between 1995 and 1997, with most of the underground work in the residential renovations sector. According to this study, in Ontario, 53 per cent of all employment in repair construction and 44 per cent in alterations and improvements was underground. For new housing the figure was 12 per cent and for non - residential construction 10 per cent. Unfortunately, no time series information is available so one does not know if the relative importance of underground activity has increased over time.

It is important to note that the estimates of output in the construction sector produced by Statistics Canada are based on more than the income reported to taxation authorities. Statistics Canada imputes income to the sector based on employment data, building supplies sales, and other relevant information. From this perspective, the growth of the underreporting to the tax authorities will not necessarily lead to an underestimation of the output of the sector.

While a comprehensive study of construction productivity trends, the CSLS report *Productivity Trends in the Construction Sector in Canada: A Case of Lagging Technical Progress* did not directly address the measurement issue. It concluded that more research was required before a conclusion could be reached on whether measurement issues were affecting the measurement of construction sector productivity in Canada. (CSLS, 2001: 47)

Part III: The View of Construction Industry Practitioners in Canada

Based on interviews conducted with seven expert practitioners (respondents) in the construction industry in Canada, this Part explores the practitioners' perceptions of construction industry productivity and issues affecting its measurement. This Part is divided into seven sections that reflect the seven primary survey questions.[7] A final section notes many additional pieces of information provided by respondents, which were not solicited directly in the survey questionnaire.

Are Statistics Canada Productivity Growth Estimates Consistent With Industry Perceptions of Productivity Growth?

Respondents were told that official estimates from Statistics Canada show labour productivity in the construction industry had advanced at an average annual rate of 0.3 per cent between 1981 and 2005. They were also told that this rate was only approximately one-quarter the rate of productivity growth in the overall business sector of the Canadian economy, which averaged 1.3 per cent over the same period. [8] They were then asked if this "very poor" rate of productivity growth in the construction industry was consistent with productivity trends they had observed.

Five of seven respondents said that the official statistics were not consistent with their perceptions of construction industry productivity growth. One respondent argued that looking at productivity trends in the construction industry as a whole was not a useful exercise since the industry was so diverse. The respondent also claimed that he did not find the Statistics Canada data alarming.

Two respondents did believe that the Statistics Canada data reflected productivity growth in the industry, but in a qualified way. One respondent identified misconceptions in the construction industry about what productivity actually is as a reason why he did not find the low productivity growth rate inconsistent with his observations. He remarked that no one likes to hear that they are unproductive and that while there has been a good deal of quality improvement in construction, that there is not necessarily a direct link with productivity improvement. The other respondent noted that while construction techniques have improved, many projects have become more complicated. He believed that this increasing complexity had not been matched by improved management. He attributed poor productivity performance to this relatively weaker management.

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[7] A list of the practitioners interviewed and a duplicate of the survey questionnaire are contained in Appendix I.

[8] Since the survey was conducted in early 2006, Statistics Canada has revised its productivity estimates. For this reason, these figures are not consistent with those that appear in other Parts of the paper.

Has There Been Significant Task-Based Productivity Growth in the Construction Industry?

As was noted in Part II, task- or activity-based productivity measurement involves measuring the change over time in the number of hours required to complete a specific task, e.g. installing 10 square metres of ceiling tile. If the number of hours required to perform a task falls, then all else being equal, productivity has improved. Respondents were asked whether significant task-based productivity improvement was consistent with their experience in the industry.

Six of seven respondents said that they felt there had been significant task-based productivity improvement. One respondent stated that the task-based productivity measurement was "more valuable" than aggregate productivity measurement. The respondent also claimed that most of the task-based productivity gains had occurred in major commercial, institutional and industrial projects. Another respondent claimed that these task-based productivity improvements were the result of better training, equipment and workplace management. The lone respondent to disagree with the suggestion that there have been widespread improvements in task-based productivity claimed that many trades and tasks had not seen much productivity improvement.

Specific Information on Productivity Growth in the Construction Industry

Respondents were asked if they had any specific information on productivity growth at the task, firm or industry level. All respondents provided examples of tasks that had seen some productivity improvement. One emphasized that he did not feel that any of the improvements he had observed had been particularly significant.

Examples of productivity improvements cited were in the areas of carpentry, hoisting, and welding. One respondent stated that between the mid 1970s and the early 2000s labour requirements for carpenters constructing foundation formwork had decreased by 50 per cent, implying a doubling of productivity. Three other respondents attributed improvements in carpentry productivity to power tools like the pneumatic hammer. Hoisting combined with increased prefabrication and modularization was claimed by one respondent to have led to "incredible gains" in productivity. The automatic welding machine was cited as a key source of productivity improvements in welding.

One respondent provided the example of the labour time reductions associated with plumbing a "one-and-a-half bath" house. He claimed that the plumbing took 40 hours in the 1970s and 8-10 hours today, and attributed this productivity improvement to changes in materials.

Respondents offered many other examples of tasks where productivity had improved. One respondent mentioned the installation of engineered wood flooring compared to traditional hardwood flooring as a task for which the number of hours required had decreased significantly. Another respondent claimed that increasing specialization had increased task productivity, and he gave the example of workers who specialize only in scaffolding. Finally, one respondent pointed to large improvements in earth moving productivity owing to new more powerful and larger equipment.

Underground Economy

Respondents were asked if they believe that there is significant underreporting of revenue in the construction industry. All respondents agreed at least to some extent with this statement. All respondents claimed that the underground economy was very large in residential construction, especially in renovations. One respondent characterized the scale of underground residential construction as “booming” and “unbelievable.” One respondent believed that 50 per cent of residential construction was underground. Several respondents claimed the large-scale industrial and engineering construction had almost no underground activity. These results are fairly consistent with other studies (Part IV).

Opinions were mixed about the presence and scope of the underground economy in commercial and institutional construction. Several respondents stated that there was significant underground activity in renovations and interior work in commercial construction. One respondent stated that government contracts for construction were often prone to underground activity, since bidders employing labour underground were able to out-bid legitimate competitors. Another respondent stated that he was aware of “extremely little” underground activity in institutional, commercial and industrial construction.

One respondent estimated that overall the underground economy accounted for 20 per cent of the construction industry and that smaller contractors were more likely to participate in underground activity.

When asked about whether the underground economy had been increasing in importance over time, many respondents cited the introduction of the Goods and Services Tax in 1991 as the point at which underground activity increased significantly. This finding is also consistent with previous studies (Part IV), for example O’Grady (1998).

Quality Improvement

Based on the hypothesis that Statistics Canada may not be capturing all of the quality improvements in construction, and, therefore, underestimating the real increase in output in the construction industry, respondents were asked if they could provide examples of some quality improvements that may not be captured in the price of buildings and structures. All respondents were able to provide examples of quality improvements in construction.

Many respondents cited higher quality materials as an important area of quality improvement that may not be reflected in the price of construction: welding quality has increased and requires less maintenance; built-in “dance-floors” and other platforms increase quality by reducing life-cycle costs of structures. One example cited by two respondents was an increase in the quality of oil and gas engineering construction, refineries now work almost flawlessly the first time they are started up, whereas in the past, it may have taken three to five months to debug a refinery before it could begin operation.

Some respondents noted that safety had improved considerably, which they considered an important quality improvement. Several respondents agreed that energy efficiency had been improved, and one cited the R2000 energy efficiency program as a reason for this.

Not all quality changes are improvements. One respondent suggested that the price of road construction was increasing, because complexities of road construction had increased with a shift from new road building to repairing existing roads. A similar sentiment was expressed with respect to major industrial and engineering structures like oil refineries, that the work was becoming more costly and time-consuming because the nature of the work was moving from green-fields construction to repair of existing structures.

One respondent stated that he believed the quality of many construction materials had in fact declined. He stated that materials were now designed with limited lifespans, whereas in the past many materials had been more durable.

Technological Innovations

Respondents were asked if they could identify major technological innovations that had increased labour productivity in the construction industry. All but one of respondents were able to identify at least some major productivity-enhancing technological innovations:

- Bridge shooting: a bridge is constructed on one bank then rolled out or “shot” across a river. One respondent stated that this technique has reduced the cost, time, and environmental impact associated with bridge construction;
- Overpass building using earth as the support structure until the concrete is set, then tunnelling out the earth underneath the completed overpass.
- The construction of platforms or the use of manlifts instead of ladders or scaffolding;
- Modularization and prefabrication: pipe racks and cat crackers for oil refineries, control modules for various types of industrial and engineering construction, and the use of hoisting equipment to install modules

- In residential construction prefabricated cabinetry, staircases, plumbing, roof trusses, and engineered wood;
- The use of the Global Positioning System in earth moving and hoisting;
- Equipment with guaranteed reliability and scheduled maintenance to avoid costly breakdowns; and
- Information and communication technologies including those used for procurement, scheduling and other administration have completely changed the administrative side of the construction industry in the past five years, according to one respondent.

One respondent did not believe that technology was making a big impact on the pace at which an overall project was completed. Similarly, another respondent claimed that the technological innovations had been helpful but that management and scheduling of construction projects were limiting the benefits of technology.

In terms of timing/scheduling one respondent felt that the pace of innovation had been much faster in the past decade (1995-2005) than in the decade 1985-1995 and that there had been a great deal innovation between 1975 and 1985.

Prework[9] (prefabrication, modularization, and preassembly)

Respondents were asked if there was a trend toward increasing prework in the construction industry in Canada and were asked if they saw any implications for productivity measurement.

All respondents agreed that prework was an important trend in industrial construction, but one respondent did note that there had always been a large amount of prefabrication in industrial construction. All respondents also agreed that there were significant productivity gains associated with prework and many attributed these gains to the controlled environment that could be obtained when work was moved away from the construction site. Many cited the increased safety associated with prework and especially with building components on the ground and then hoisting them into place instead of building them in the air. One respondent from Alberta stated that the extent to which prefabrication and modularization could be applied was being limited by road infrastructure.

One respondent noted that the trend to prework in the United States had begun to impact the residential and commercial construction industries, but that this was not yet occurring to the same extent in Canada. Another respondent confirmed that prework was quite limited in residential construction, but offered the example of panelized homes.

[9] See discussion for definition of prework, which include prefabrication, modularization and preassembly in Part IV.

During the interviews it also became clear that there was considerable uncertainty as to whether prework was taking place in the construction industry or the manufacturing industry. Most respondents believed that prework, regardless of where it was carried out should constitute part of the construction industry.

Additional Comments

Many respondents were unsure of how Statistics Canada compiles not only productivity statistics, but also the employment, hours and output statistics that are needed to calculate productivity. Many respondents were unaware that Statistics Canada imputes output to the construction industry based on various measures,[10] and they disputed Statistics Canada's assertion that it is capturing most underground activity in its construction industry statistics.

One respondent raised the issue of how the hours of workers who work in construction, but who are primarily employed in another industry, are measured. He noted that firefighters, for example, often have second jobs in construction because of their flexible primary work hours and their knowledge of building codes and construction techniques.

One respondent noted that there has been an increase in apprenticeship in the 2000s compared with the 1970s, 1980s and 1990s. He proposed that this trend might have reduced the amount of time that workers were able to devote to work as opposed to training, and offered this as a possible reason for slow productivity growth.

[10] See Part IV for complete discussion of how Statistics Canada measures nominal output in the construction industry.

Part IV: The Methodology of Productivity Measurement in Canada

This part of the report has four sections. The first discusses what productivity is and why it is important to the construction industry. The second section explores why productivity is more difficult to measure in the construction industry than in other industries. The third section examines how Statistics Canada measures productivity in the construction industry. The fourth section addresses the impact of prework on construction industry productivity measurement in Canada. Conclusions about the merits of the current statistical methodology of construction industry productivity measurement are left to Part V.

Why is Construction Productivity So Hard to Measure?

This section uses an example to illustrate some of the basic concepts involved in measuring real or constant-dollar output, in the construction industry on the bases of value added and gross output per hour

Example

There are several problems that hamper the measurement of productivity in the construction industry, but the most important is the difficulty of accurately measuring real output. As discussed in the previous section, real output is equivalent to physical output and gross output. It is important to measure, because looking at current-dollar output over time is misleading for two reasons. First, current dollar output does not account for inflation, and second, it does not account for changes in the quality of output, which may not be captured in price movements. Real output, therefore, is the true measure of the quantity of goods being produced. Table 1 offers a simple illustration of inflation, quality change, and the calculation of real output. The example is of the price and quality changes that affect a simple product, a light bulb, over the course of five years. It is important for the reader to understand the fundamentals of how deflation is carried out before a discussion of relatively complex issues surrounding deflation in the construction industry is undertaken. Readers familiar with the general concept of quality adjustment may skip this example without missing any key components of the study.

The price of a typical light bulb, in this case a 100-watt bulb, increases over five years from $1.50 to $1.90. At the same time, the lifespan of a typical 100-watt bulb increases from 2,000 to 2,310 hours. In this case, let us assume that lifespan is the only measure of the quality of a light bulb. Clearly, both the quality and the price of this light bulb have increased over the five years. But how much of this increase in price is due to the increase in quality, and how much is due to price inflation caused by external factors, for example, the forces of supply and demand for light bulbs?

Table 1: Example of Inflation,quality change, and deflator							
Typical Lightbulb, 100-watt							
	Price per bulb, current dollars	Lifespan, hours	Price per bulb per hour, current cents	Price per bulb inflation rate, per cent	Price per bulb per hour inflation rate, per cent	Constant quality price index for typical 100-watt lightbulb, (year 1 = 100)	Price per bulb, constant (year 1) dollars
	A	B	C = A * 100 / B	D = growth rate of A	E = growth rate of C	F = C / 0.075	G = A / F * 100
Year 1	1.50	2,000	0.075	..	..	100.0	1.50
Year 2	1.60	2,100	0.076	6.67	1.59	101.6	1.58
Year 3	1.70	2,150	0.079	6.25	3.78	105.4	1.61
Year 4	1.85	2,240	0.083	8.82	4.45	110.1	1.68
Year 5	1.90	2,310	0.082	2.70	-0.41	109.7	1.73
Note: This example is for illlustration only and the values used are not intended to be realistic.							

One way to account for inflation and changing quality is to hold quality constant in order to observe the pure price change. In this simple example, quality is held constant by looking at the price per hour of light (see column C), that is, the price per bulb (column A) divided by the lifespan of the bulb (column B). Next the price-per-bulb, or total, inflation rate is calculated (column D). This is the rate that would most likely be observed by the consumer or casual observer. It is, however, not a good measure of the change in the real value of the light bulb, because quality has improved, so the real value has risen along with the price. The per-hour of light inflation rate (column E) is a superior measure of price inflation, because it holds quality constant. In fact, we can see in this example that the cost per hour of light of a 100-watt light bulb fell between Years 4 and 5. This fall occurred because, even though the price of the bulb went up in absolute terms from $1.85 to $1.90 (column A), the quality of the bulb increased from 2,240 to 2,310 hours lifespan (column B). As a result, the consumer could in fact buy a better bulb in year 5 than in year 4 for the same amount of money. Finally, when the price of a bulb is calculated in real (or constant or inflation- and quality-adjusted) terms (column G), we can see that real price of a 100-watt light bulb has increased from a $1.50 to a $1.73 in (constant) Year 1 dollars, as opposed to the nominal price, which increased from $1.50 to $1.90 in current dollars.

The example given above served to illustrate how real (inflation- and quality-adjusted) price series are calculated. At the same time, it also serves as a contrast with the difficulties that are faced by those who attempt to measure real prices in the construction industry. While a light bulb is a simple product, in reality, many products are more complicated. Even a light bulb comes in various powers (40W, 60W, 100W, etc.) and light bulbs of the same power may have different lifespans. If a single light bulb is a complex product, it is certainly far less complex than a residential house, apartment building, oil refinery or aluminium smelter. The fundamental difficulty faced by those who attempt to measure the output of the construction industry, in real terms, is the diverse and complex nature of that output.

This heterogeneity of construction makes current-dollar output quite challenging to deflate in an accurate way. Unlike our fictitious light bulb that had only one dimension of quality, lifespan, most products produced by the construction industry have a large number of potential measures of quality. It is not clear what the common denominator should be for a residential house or a shopping mall. Various methodologies have been proposed to resolve this problem.

What Price Indexes are Used in the Construction Industry?

This section briefly explains the general types of indexes used to deflate the nominal value (current-dollar) of construction output. It discusses the most important indexes used by Statistics Canada to build deflators for construction output in Canada.

Model Price Indexes (also known as estimation price indexes)

A model price index avoids the heterogeneity problem by holding constant over time a detailed specification for a structure or different components of a structure. Construction firms or informed individuals, such as cost-engineers or contractors, are then asked to estimate the selling price of the model or components of the model on a regular basis. In this way, the pure price change can be observed, while quality is held constant.

Generally, the preferred methodology is to have the respondent price the structure with which he or she has the greatest expertise. This preference leads to an aggregated and disaggregated approach. (Pieper, 1990: 255) The aggregated approach involves one respondent estimating the price of an entire project. This approach tends to be employed for relatively simple structures like a single house. For more complicated structures, like an industrial or institutional building, the disaggregated approach is favoured. (Mohammadian and Seymour, 1997: 3) It involves respondents estimating the price of various components. This approach is employed, because it is unlikely that one respondent would have expertise in the construction of all of the components of a large and complicated project.

Examples of model price indexes developed and used by Statistics Canada in the estimation of construction industry productivity are the “New Housing Price Index,” the “Apartment Building Construction Price Index,” and the “Non-Residential Building Construction Price Index.” All three are discussed in detail below.

The New Housing Price Index

The New Housing Price Index (NHPI) is a model price index. It tracks contractors’ selling prices for new residential houses of a detailed specification that remains fixed between two consecutive periods and contractors' estimates of the current value (at market price) of land. Land value is then subtracted from total selling price to determine the value of the house only. All three series (house and land, land only, and house only) are converted to indexes and published monthly by Statistics Canada.

The NHPI is constructed through monthly interviews with builders in 21 metropolitan areas. Interviewees mainly build single unit houses in a volume such that they have a good idea of the selling prices for comparable structures. Builders are selected based on market intelligence and building permit information and are often those who develop entire subdivisions on large tracts of land. At the same time, builders who construct fewer units are often included as well, as long as they can price a comparable model over a period of time.

Apart from the total selling price for the house and land, and a separate appraisal of land value, the interview solicits detailed information on the physical and non-physical characteristics of the model house being priced. The model is selected after discussion with builders and is representative of the current construction portfolio of each builder being surveyed. The value of quality changes, as estimated by the respondent, is most often used to adjust the reported price in order to obtain a pure (quality-adjusted) price change. The price report was developed in the 1980s with the input and feedback from respondents and the Canadian Home Builders' Association.

The Apartment Building Construction Price Index and the Non-Residential Building Construction Price Indexes

Like the New Housing Price Index, the Apartment Building Construction Price Index (ABCPI) and the Non-Residential Building Price Indexes (NRBCPI) are also model price indexes. However, unlike the NHPI, where builders were asked to price an entire model house, in the construction of the ABCPI and the NRBCPI, builders are asked to price components of the model building. The model apartment building is selected by Statistics Canada with the advice of the Canadian Mortgage and Housing Corporation. The model non-residential buildings are a warehouse, a shopping centre, a school, an office, and a light factory. The warehouse and school are based on models constructed in the early 1980s, and shopping centre, school and office are based on models constructed in the early 1990s.

This disaggregated approach is taken, because, unlike in the case of a single unit house, it is unlikely that one person would be involved in all aspects of building a structure as complicated as an apartment building or shopping mall. Respondents are more likely to have a specific area of expertise. The construction of the model building is divided into five main trades: architectural, structural, mechanical, electrical, and the general contractor's overhead and profit. "Representative sample items of work-in-place are selected for each category for subsequent re-pricing." (Mohammadian and Seymour, 1997: 3) Approximately 200 items are priced for each model building in each location. Locations surveyed are the seven Census Metropolitan Areas (CMAs): Halifax, Montreal, Toronto, Calgary, Edmonton, Vancouver, and the Ontario part of the Ottawa-Gatineau CMA. The cost of land, land assembly, design, development and real estate fees are not included in the ABCPI or NRBCPI.

Hedonic Price Index (also known as a characteristic or regression price index)

A hedonic price index uses the statistical technique known as regression to attempt to adjust for changing quality in construction projects. The best-known example of such an index is the US Census single family homes index. Basically, the methodology uses statistical techniques to link the price of a house with its characteristics. In the case of the US Census single family homes index, the characteristics are square feet of floor space, number of bathrooms and stories, metropolitan and regional location, presence of a garage, basement, and central air conditioning. Fireplaces and lot size were added in 1974. (Pieper, 1990: 241) This technique was largely unsuccessful when applied to the multiunit residential sector, and Pieper (1990: 254) knew of little work in other areas using hedonic price indexes. Similarly, a review of the literature on construction price indexes did not reveal any new work using hedonic indexes since 1990. Hedonic indexes are not used in Canada to produce construction price statistics.

The major disadvantage of hedonic price indexes is the inability to quantify all of the quality aspects of a construction project. Pieper (1990: 256) notes that important aspects of quality like design and the quality of materials are very difficult to quantify. He also notes that one of the main problems with trying to develop a hedonic index for multi-unit residential and non-residential buildings is that these types of structures tend to be far less homogenous on a square-foot basis than single family homes, and that the only data available were region, square-footage and number of bathrooms. Pieper also notes that proper regression analysis requires many observations and that for many smaller construction sectors this could be a problem. He does suggest application of the hedonic technique to highway construction, but it does not appear that any attempt to follow up on his suggestion has been made in the United States or elsewhere.

Bid Price Index

A bid price index is compiled by collecting information on the winning bids made on a particular type of construction project, as long as some measure of output is available, like square feet. Alternatively, if bids are made on the components of a construction project, as is the case in many types of engineering construction, an average of the winning bids on each component can be compiled. This type of index, however, does not surmount the problem of heterogeneity of output, unless some relatively homogeneous measure of output, like square feet, is both appropriate and available. Measures of output tend only to be appropriate when the category of output is narrowly defined, that is specified in detail (Pieper, 1990: 253). Similarly, Mohammadian and Seymour (1997: 5) state that bid price indexes are more suited to sectors where there is a large number of contracts for relatively homogeneous projects using similar construction methods. Pieper (1990: 254) and Mohammadian and Seymour (1997: 5) both argue that bid price indexes are of limited utility due to the lack of a homogeneous measure of output.

Pieper offers the US Federal Highways Administration (FHWA) index as an example of a bid price index. The FHWA index is based on bid data from six components of highway construction collected by state. However, Pieper observes that the average state prices for each of the components vary enormously, for example, in 1981 price per cubic yard for excavation ranged from $0.78 to $15.71. (Pieper, 1990: 253) It seems almost certain that even "excavation per cubic yard" is too broad a category to capture true price change since it encompasses activities that are quite different in nature.

Statistics Canada uses the bid price methodology to develop output price indexes for provincial highway construction. Mohammadian and Seymour (1997: 5) state that the bid price index cannot be applied to most construction sectors because of the inability to collect sufficient data at reasonable cost.

Input Cost Indexes

Input cost indexes track the cost of the inputs used to produce a construction project, usually a weighted average of a wage labour index and a building materials index. These indexes are relatively easy to construct, because they can be built up from records collected from businesses on a regular basis by statistical agencies, such as union wage rate agreements or the selling prices of materials used in construction like cement, engineered lumber, or electrical wiring.

As discussed earlier (Part II), for the purposes of deflation, input cost indexes are not as desirable as output price indexes. However, the difficulty and cost of producing output price indexes often means that input cost indexes are used. Input cost indexes are potentially problematic for output deflation, because they take no account of variations in productivity and contractors' overhead and profit margins. Furthermore, these indexes often use weights for different inputs that remain fixed for long periods of time. Fixed weights do not allow for the inevitable changes in input mix resulting from technological change. In spite of their problems, these indexes are often "very simple and the least expensive to construct and maintain." (Mohammadian and Seymour, 1997: 2) When no alternative to an input-cost index is available, the use of input cost indexes is better than no deflator at all. Similarly, it is arguable that the use of input cost indexes is superior to the use of a distantly related price index, for the deflation of a particular output series.

All nominal output in the engineering construction industry in Canada is deflated using deflators constructed from input cost indexes. Statistics Canada uses three separate deflators to deflate all of engineering construction, a highway construction deflator, a railway construction deflator, and a deflator for all other output of the engineering construction industry. The Income and Expenditure Accounts Division of Statistics Canada is currently developing separate deflators for each of the components of engineering construction, so that they can be deflated separately, instead of using the aggregate approach. Statistics Canada believes this project will result in a better deflator for engineering construction output.[11]

Examples of input cost indexes that are used by Statistics Canada to estimate construction industry productivity are the "Construction Union Wage Rates Index" and "Industrial Products Price Index."

Construction Union Wage Rate Index

The Construction Union Wage Rate Index tracks the collective agreement wage rates for 16 important trades in building construction in 20 metropolitan areas. Both basic wage rates and wage rates including selected pay supplements like vacation pay, statutory holiday pay, pension contribution, and employer's contribution to private plans, health and welfare plans, industry promotion and training funds (Statistics Canada, 2006: Footnotes to *Construction Union Wage Rate Index* on Statistics Canada website). Statistics Canada obtains data for this index from collective agreements that are provided by construction labour relations associations across the provinces.

City weights are derived from estimates of gross earnings of each trade in a metropolitan area based on 1991 Census data.[12] After a collective agreement expires, the prevailing rates are kept in place until a new collective agreement is negotiated.

The Construction Union Rate Index has a 40 per cent weight in the deflator used to deflate the Alterations and Improvements component of residential construction. Indirectly, it is also used to deflate part of repair construction, because repair construction is deflated using an implicit price index based on the alterations and improvements component of residential construction.

Industrial Products Price Index

The Industrial Products Price Index (IPPI) tracks the prices of major commodities sold by manufacturers in Canada. Data is collected using a sample survey of manufacturers and other surveys. Prices are measured "at the factory gate" and, therefore, represent what the manufacturer receives, not the price that is paid by the purchaser. Factory gate prices exclude indirect taxes like sales taxes and tariffs and exclude service costs of transporters, wholesalers and retailers.

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[11] This information is based on conversations with Statistics Canada officials in early 2006.

[12] The most recent (derived from the 1991 Census) weights in per cent were as follows: St. John's, NL, 0.80; Halifax, 1.77; Saint John, NB, 0.85; Quebec, 3.72; Chicoutimi, 1.17; Montreal, 15.70; Ottawa, 5.18; Toronto, 26.08; Hamilton, 4.43; St. Catherines, 2.58; Kitchener, 2.32; London, 2.33; Windsor, 1.51; Sudbury, 1.30; Thunder Bay, 1.07; Winnipeg, 3.25; Calgary, 5.21; Edmonton, 6.98; Vancouver, 11.91; Victoria, 1.84. (Statistics Canada, 2005: 24-26)

The IPPI is the basis for a residential material price index[13], which is given a weight of 60 per cent in the deflator used to deflate the Alterations and Improvements component of residential construction. Indirectly, it is also used to deflate part of repair construction, because repair construction is deflated using an implicit price index based on the deflator for the Alterations and Improvements component of residential construction.

What is the Problem with Deflating Construction Output?

Earlier in this part, it was noted that the main problem with measuring construction productivity was how to measure real output. The concepts of real versus nominal output and the methodology normally used to deflate nominal output were discussed. This section will address the specific problems faced when nominal construction output is to be deflated.

In the example of the light bulb in the first section, output was relatively homogeneous. The only difference between a light bulb produced in one year, and a light bulb produced in another year, was the change in quality, measured uniquely by the lifespan of the bulb. This change in quality could be adjusted for by using a common denominator, like hours of light. In contrast, construction output is extremely heterogeneous; almost every construction project is unique. Trying to find a uniform measure of the quality of construction projects is exceedingly difficult. Square footage is the most common proxy measure of quality in construction projects, but it is clear that size alone is an inadequate measure of quality change. A simple example is the quality of the fittings installed in a house. One house might be very large, yet have low quality fittings, while another may be smaller and have better quality fittings. Clearly, square footage is not a perfect proxy for quality.

Historically, this difficulty has led often to input-cost based measures of price change being used to deflate construction output. To generate an accurate measure of real output growth based on this procedure, two assumptions must hold: productivity and profit margins must be constant. Essentially, use of an input-cost based deflator assumes that the price of output moves in step with the price of inputs. In both the short run and the long run, this assumption is false.

Producing more output for a given amount of input is the definition of productivity growth. Looking at things the other way around, even if input prices are rising, output prices may rise more slowly, or even fall, since less input is needed to produce a given amount of output. If productivity growth is taking place, then an input cost index will tend to grow faster than an output price index. If this input cost index is then used to deflate output, the amount of real output will be understated.

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[13] This "residential material price index" which is based on the IPPI should not be confused with Statistics Canada's Residential and Non-Residential Building Material Price Indexes which were maintained monthly between January 1981 and June 1990, at which point they were terminated.

Input cost indexes are useful for deflating the value of wages or materials. However, many observers of the construction industry have questioned the appropriateness of using input cost indexes to deflate construction output.

Two key questions that this paper seeks to answer are to what extent is Statistics Canada relying on input cost indexes to deflate construction output, and is the use of such input-cost based deflators resulting in underestimation of real output growth, and therefore productivity growth, in the Canadian construction industry.

How does Statistics Canada Calculate Construction Industry Productivity Statistics?

This section will examine in detail how Statistics Canada calculates productivity in the construction industry. First it presents a general overview of the data sources used by Statistics Canada to compile productivity statistics. Then it turns to the issue of how nominal (current-dollar) output is measured, including a complete discussion of the impact of underground activity on measurement in the construction industry. After that, the section turns to a detailed discussion of the deflation methodology employed by Statistics Canada in the construction industry to arrive at real (constant-dollar) output (value-added) estimates.

General Information on Statistics Canada Productivity Data Sources

According to Statistics Canada (2001a: 154), the data sources used to compile the official productivity estimates are as follows:

> In order to produce productivity growth estimates, various data sources from Statistics Canada's survey areas and the System of National Accounts are integrated. In particular, the productivity program requires data from the following:
>
> 1. the Input-Output Division, which provides the structure of the economy (in terms of industries, the commodities produced and used, and how they change over time) in both current and constant prices that is so essential to the production of aggregate estimates that are built from the ground up at the industry level;
> 2. the Labour Statistics Division, which provides employment numbers and hours worked to estimate the labour input;
> 3. the Investment and Capital Stock Division, which provides estimates of year-end net capital stock to estimate capital input; and,
> 4. the Industry Measures and Analysis Division, which produces current estimates of GDP in constant prices, for preliminary estimates of productivity for the three most recent years.

Output by Industry

Output by industry is estimated based on different data sources and methodologies depending on whether it is being estimated on an annual or sub-annual (monthly or quarterly) basis. This study will focus on annual data, therefore issues specifically related to sub-annual data will not be examined in detail.

> For all but the most recent two years, the annual estimates of GDP by industry are derived within the framework of the Input-Output (IO) tables. The data sources are typically annual surveys or censuses.
>
> For two full years and part of the third year following the most recent IO tables and also for sub-annual periods, the lack of applicable data, particularly on intermediate inputs, precludes a value added calculation. Estimates of GDP in these periods are projections that are based on such proxy indicators as output or employment. These indicators are usually obtained from monthly surveys.
>
> As a result of using different data sources and methodologies, the annual GDP and the yearly totals of the independently produced monthly estimates are not identical. However, this difference between the two sets of estimates is eliminated by integrating the annual benchmark value into monthly GDP estimates as soon as the most recent Input-Output tables become available. This blending process, called benchmarking, generates a series which moves as much as possible with the original monthly series and sums to the annual benchmarks. (Statistics Canada, 2002: 15)

The Input-Output tables contain two sets of accounts. Commodity accounts show the supply and disposition of individual commodities, while industry accounts record the output and the costs of production of industries. Value added for an industry is calculated by subtracting the value of intermediate inputs from the value of output.

How Statistics Canada Estimates Nominal (current-dollar) Output

Practitioners in the construction industry often point to underground activities as an important culprit for the underestimation of gross domestic product and the low level of productivity that results from it. In this sub-section, we will first describe how gross domestic product for the construction industry is compiled by Statistics Canada. We will then examine the difference between underground and unmeasured activities and their estimates for Canada's construction industry. Finally, we will identify the conditions in which unmeasured activities could significantly affect productivity levels and productivity growth and determine whether or not these conditions are being met in Canada.

Gross Domestic Product for the Construction Industry in Canada

In Canada, gross output for the construction sector in the System of National Accounts (SNA) is not based on the North American Industry Classification System (NAICS). In fact, the computation of gross output is based on types of construction rather than on industrial classification. For example, if a retail company directly employs construction workers to build a new store, the output (the store in this case) will be allocated to the commercial (non-residential building) construction industry, not to the retail trade industry, as it would be with NAICS. In other words, own account construction is part of the construction sector.

This feature in the SNA allows for the calculation of construction industry gross output in a different way than for other industries. While for most industries data are derived from industry surveys and administrative data, gross output in the residential construction sub-industry is estimated using indirect indicators or demand side indicators. For example, the value of new housing is estimated by using a combination of housing starts, average value of building permits and work put in place coefficients, the latter being used to allocate production over the different periods (Statistics Canada, 1994)[14]. With these measures, Statistics Canada can measure the value of new housing[15] put in place in each period. Other costs, such as legal, architectural and GST to name only a few, are then estimated and added to gross output in the new residential construction sector. Work on building conversion, based on building permits, and mobile homes, based on manufacturers' shipments, are also included.

The same approach is used to estimate the gross output in the alterations and improvements component of residential construction. In this case, household expenditure surveys are used to estimate spending for both material and contract work. Similarly, real estate commissions, which are included in transfer costs, do not rely on tax data. They are instead calculated using an average commission rate to the reported value of sales supplied by the Canadian Real Estate Association.

In other words, the estimates of gross output for the residential construction sub-industry are independent of the receipts declared or reported by businesses and self-employed workers. As will be discussed in the next sub-section, the indicators just outlined cover most of the formal and informal economic activity in the residential construction sub-industry, which means that while there might be a large underground economy in residential construction, it does not follow that gross output is underestimated.

Statistics Canada did try to develop an industry survey to collect data directly from the construction industry as it already does for most other industries, such as manufacturing and retail. However, data for this survey covers only the 1998-2000 period. The survey, called "Survey of the Construction Industry", was discontinued after 2000, because the estimates fluctuated considerably from year to year and were deemed

[14] The discussion of Statistics Canada's methods for estimating GDP in the construction sector is based on Statistics Canada (1994) and information given over the phone by numerous Statistics Canada employees.
[15] The value of new housing is obtained from the product of housing starts and average value of building permits and the coefficient put in place during the period and previous periods.

unreliable. Moreover, the response rate was very low, and the industry was less interested in the data because of the long lag between the reference year and the release of the data.

For the non-residential and engineering construction sub-industries, employment and administrative statistics, including tax data, are the main sources of data for the estimation of gross output. However, it is generally assumed that the underground economy in the construction industry is concentrated in residential construction. This assumption is supported by the results of the survey of practitioners conducted for this study presented in Part III. In effect, it would be much harder for large companies operating in non-residential and engineering construction to systematically fail to declare a part of their business income[16], a process called skimming. At the intermediate level, they might employ smaller contractors to do part of the job and these contractors might fail to report some of their income. However, this is irrelevant for the calculation of GDP because, as with intermediate inputs, counting intermediate skimming would be double counting. Therefore, because underground activity in non-residential and engineering construction is likely to be concentrated at the intermediate level, one can safely assume that estimates of gross output for these sectors are reliable.

Underground and Unmeasured Economic Activity

If one thing is in no doubt about the Canadian construction industry, it is the existence of an extensive underground economy in residential construction. Moreover, findings of earlier studies suggest that the underground economy in residential construction is not only prevalent, but might also be growing relative to the size of the industry. O'Grady *et al.* (1998) point to the introduction of the GST in 1991, the poor economic conditions of the early 1990s, and the growth of the self-employment in the industry as the three principal drivers behind the growth of underground activity in the construction industry in Ontario.

In their report, O'Grady *et al.* (1998) estimate that Ontario's underground construction industry increased by between 50 and 100 per cent between 1990 and 1997. For the 1995-1997 period, he estimates that 32 per cent of income in residential construction in Ontario was underground. For residential repair, he estimates an underground rate of 53 per cent. These results point to a large and prevalent underground economy in residential construction.

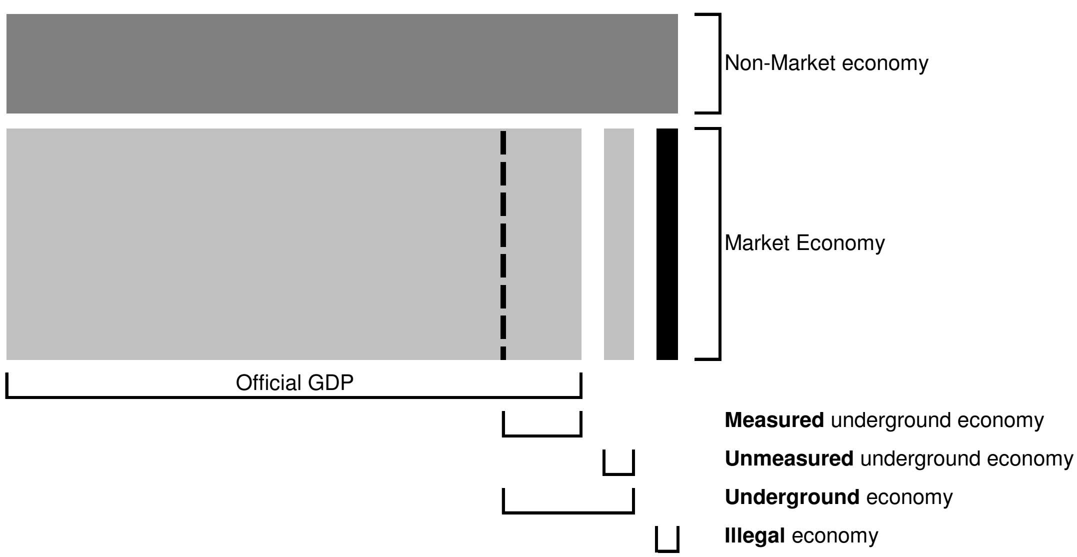
Other studies, including the survey conducted in conjunction with this report (Part III), reach similar conclusions. For example, a World Bank study (2002) on the size of the informal economy in numerous developing and developed economy estimated Canada's overall shadow economy at 16.3 per cent of GDP for 1999-2000. In the same study and using a different method, the authors estimated that Canada's informal

[16] Because of their larger size, construction companies in those sectors would have to involve numerous employees and the cost of being discovered (reputation, future contracts) would be much larger than for a small contractor.

economy grew from 12.8 per cent of GDP in 1989-1990 to 15.8 per cent of GDP in 2001-2002. O'Grady *et al.*'s (1998) short literature review on the subject shows similar results, with Canada's underground economy ranging from 4.8 per cent to 21.9 per cent depending on the period and method used. The results for the construction industry were, as discussed above, much higher.

These results appear to reinforce the idea that nominal gross output suffers from important measurement issues. To better understand why this is not necessarily the case, it is important to explain the difference between underground and unmeasured economy. Exhibit 1 provides a summary of the different components captured and not captured by official GDP measures. In contrast to the Canada Revenue Agency, which has an incentive to lower the level of the underground economy, Statistics Canada's role is to capture all legal economic activity by minimizing the unmeasured part of the economy, i.e. the part not captured by their GDP measure. However, it remains true that underground transactions are generally harder to capture than reported transactions. Thus, a larger underground economy *could* translate into a larger unmeasured economy.

Exhibit 1: Underground versus Unmeasured Economy



Source: Slightly modified from Statistics Canada (1994)

To determine if the calculation of gross output in residential construction is underestimated by the official statistics, one needs to evaluate the coverage of each indicator used to derive the result. For example, if Statistics Canada used tax data, i.e. receipts reported or declared by construction businesses, to estimate gross output in the construction sector, an increase in the underground economy would *necessarily* lead to an increase in the unmeasured economy. However, Statistics Canada does not use taxation statistics, which means we need to carefully evaluate the possibility of mismeasurement due to an increase in the size of the underground economy for the main indicators for the residential construction sector.

Table 2: Measurement issues in the residential construction sector

Indicator	Source	Estimation issues	Possible under-measurement
Housing starts	CMHC	• No source of error linked to underground activity identified.	None
Value of building permits	Building permits survey	• Builders underestimate the cost to facilitate income hiding and to save on the cost of the permit (except in Quebec).	• 5-10 per cent undervaluation depending on the type of housing ⇒ $1,112 million for single dwellings, $127 million for semi detached and row housing and $159 million for apartments. • 25 per cent undervaluation for cottages ⇒ $156 million. • 200 per cent of unreported conversions ⇒ $206 million. • 10 per cent undervaluation of supplementary costs ⇒ $111 million.
		• Municipalities outside Quebec have an interest in monitoring the value of building permits.	
		• Statistics Canada adjusts the value to reflect the estimated undervaluation, omitted material costs (such as landscaping) and builder's margin.	
		• Statistics Canada adjusts the value of cottages further based on the proportion of households owning a vacation home.	
Spending on alterations and improvements	Survey of Household Spending	• Homeowners have no direct incentive to underreport because the contractor is liable for taxes.	• 20 per cent underreporting of contract work (before the GST, 10 per cent was considered a *plausible* estimate) ⇒ $1,542 millions. • 10 per cent undervaluation for renovations in rented dwellings ⇒ $153 millions.
		• Some homeowners might underreport contract work for fear of higher property taxes.	
		• Estimates for renovations in rented dwellings were benchmarked using a U.S. survey and the input-output tables and was since projected using building permits value for apartments.	

Statistics Canada (1994) reviewed in-depth the incentives for under-reporting for most indicators used in the compilation of gross output estimates for the residential construction sub-industry. That study concluded that following a 1984 revision for alterations and improvements that added $6.0 billion due to under-coverage, by 1992 the residential sector seemed to be well covered by the official GDP estimates. However, by changing the assumptions embedded in the calculation of residential construction gross output, the authors calculate an *upper-boundary* of $3,578 million (8.1 per cent of value added in the sector) for underestimation of gross output in the residential sector in 1992.

Interestingly, Statistics Canada (1992) also compares National Accounts and Revenue Canada data on net income of unincorporated construction businesses and found that in 1991, 65.4 per cent of income of these businesses included in gross output measures for the construction industry was not reported or declared to Revenue Canada. This finding emphasizes the difference between underground and unmeasured economy, showing the weak link between the two concepts in the construction sector.

Impact on Productivity Levels and Productivity Growth Measurement

To evaluate the impact of underestimation on measured levels and growth of productivity, we will assume that the Statistics Canada upper boundary for underestimation of gross output is in fact true. Moreover, because estimates for intermediate inputs in the construction industry are generally considered very reliable, we will attribute the *totality* of the underestimation to GDP.

Assuming the 8.1 per cent underestimation of value added calculated for 1992 in residential construction is still valid for 2002, it translates into an underestimation of total construction GDP of 2.66 per cent. This would in turn translate into a symmetric underestimation of labour productivity levels for Canada of 2.66 per cent. Adjusting for this underestimation would only raise construction labour productivity from 80.8 per cent of the industrial average to 83.0 per cent of the industrial average. However, these assumptions would *not* lead to an underestimation of *productivity growth,* because the underestimation of productivity levels would be proportional every year.

Still, it is possible to imagine a worst-case scenario in which the unmeasured gross output grows faster than the measured share. In this case, if we assumed that the relative size of the underground economy doubled since 1990 (O'Grady *et al.* (1998) upper estimate), the unmeasured economy would now account for 16.2 per cent of residential construction and 5.32 per cent of GDP. In this case, measured productivity levels would be 5.32 percentage points lower now than true levels (raising construction labour productivity to 85.1 per cent of the industrial average).

Moreover, if the proportion of the unmeasured economy doubled during the period, this could lead to an underestimation of about 2.6 per cent for productivity growth. In effect, while today's measure of the productivity level in the construction sector would be 5.32 per cent too low, the measure from 1992 would only be 2.66 per cent too low. Thus, labour productivity estimates would have underestimated labour productivity growth by only 2.6 per cent over the period. On an annual basis, for the 1992-2002, average compound annual productivity growth would rise by 0.26 percentage points.

In conclusion, it appears that the possibility of a large-scale underestimation of gross output in the construction industry is very small in Canada. This results directly from the method used to estimate gross output in the industry, which relies mainly on demand-side indicators rather than supply-side indicators. While contractors in the construction industry have strong incentives to underreport, consumers' incentives to do so are much lower. Though it is still possible that there is some underestimation of gross output in the construction, this underestimation, even under a worst-case scenario, cannot account for much of the weakness in productivity growth in the construction industry, nor can it account for much of the relatively low labour productivity levels reported. It does not appear to provide any answer that could explain the difference between practitioners' perceptions and Statistics Canada aggregate data on labour productivity.

The Deflation of Value Added

Because of inflation, in order to determine the real change in output, nominal (current-dollar) output must be converted to real (constant-dollar) output by use of a deflator. An output deflator is a number by which nominal output is divided in order to produce real output. Once deflated, a real output series should measure only the change in the volume of output. Real value added is calculated using what is called the double-deflation methodology. This procedure involves deflating separately the value of gross output and the value of intermediate inputs by appropriate deflators. Real value added is then calculated residually as the difference between the two series.

In the Input-Output tables, construction is divided into eight special industry aggregations also known as commodities: Residential; Non-residential building; Transportation Engineering; Gas and oil engineering; Electric power engineering; Communications engineering; Other engineering; and Repair construction. These commodities are then deflated using deflators developed by the Income and Expenditure Accounts Division of Statistics Canada. (Statistics Canada, 2001a: 35) Deflators are constructed to deflate specific series. For example, there are separate deflators for apartment buildings and for shopping malls. The price indexes that are used to construct deflators and the deflators themselves will be examined in detail below. It is in the construction of deflators for output that a potential problem of productivity measurement arises.

Table 3 summarizes the deflators currently used to deflate different commodities produced in the construction industry. In order to generate real value added, each of these commodities is deflated by the corresponding deflator.

Table 3. Summary of Construction Deflator Methodologies

Commodity/Industry (NAICS/IOIC-based)	Deflation Method	Type of Deflator	Share of total Construction Industry Value Added in 2003, current dollars, per cent[2]	
Residential Building Construction				
Single dwellings, semi-detached dwellings, and row housing	New Housing Price Index (NHPI)	Output (model) price index	23.77	33.87
Apartments	Apartment Building Construction Price Index (ABCPI)	Output (model) price index		
Alterations and improvements to existing housing (renovations)	Residential building materials index, (60% Industrial Products Price Index, 40% Construction Union Wage Rates Index)[1]	Input cost index	10.10	
Non-Residential Building Construction	Non-Residential Building Construction Price Index (NRBCPI) with an adjustment of 10 per cent for own-account construction	Output (model) price index	17.32	
Transportation Engineering Construction (SIC: Road, highway and airport runway construction)	Highways and roads are deflated by a specific index, airport runway construction is deflated using the aggregate deflator for engineering construction excluding highways and railways	Input cost index	4.90	
Oil and Gas Engineering Construction (SIC: Gas and oil facility construction)	Aggregate deflator for engineering construction excluding highways and railways	Input cost index	11.61	
Electric Power Engineering Construction (SIC: Dams and irrigation projects)	Aggregate deflator for engineering construction excluding highways and railways	Input cost index	5.48	
Communications Engineering Construction (SIC: Railway and telecommunications construction)	Railways are deflated by a specific input cost index, telecommunications construction is deflated using the aggregate deflator for engineering construction excluding highways and railways	Input cost index	0.75	
Other engineering construction	Aggregate deflator for engineering construction excluding highways and railways	Input cost index	5.38	
Repair Construction	Implicit price index for alterations and improvements component of residential construction	Implicit price index based on input cost index	19.39	

Notes:
1. The weighting used in the deflator for Alterations and Improvements to residential structures is derived from the Homeowner Repair and Renovation Survey.
2. Shares do not sum to 100 because “Other activities of the construction industry,” which account for 1.31 per cent of output do not appear in this table at this time.
Sources: Centre for the Study of Living Standards, based on discussions with Statistics Canada officials and Statistics Canada (2001a: 35-36)

Residential Building Construction

Residential building construction is subdivided into three principal components for deflation purposes. The first component includes single-family dwellings, semi-detached dwellings, row houses, and cottages. These components are deflated using the New Housing Price Index. The second major component is apartment building construction, which is deflated using the Apartment Building Construction Price Index. The third substantial component of residential construction is renovations. Renovations are deflated using a specially constructed wage and materials cost index. The Construction Union Wage Rates Index is given a weight of 40 per cent in the deflator and a special construction materials index is given a weight of 60 per cent. Several other minor components of residential construction are deflated in a variety of ways.

Residential building construction accounted for 33.87 per cent of all construction industry value added in 2003. Within residential construction, 23.77 per cent of total construction value added was derived from single-family dwellings, semi-detached dwellings, row houses, cottages, and apartment building construction, and was deflated using output prices. Alterations and improvements (renovations) are deflated using an input-cost based deflator and constituted 10.10 per cent of total construction value added.

Non-Residential Building Construction

Non-residential building construction is deflated by the Non-Residential Building Construction Price Index, which is an output-price based deflator based on the model price method. Contracted investment is given a weight of 90 per cent and own-account work a weight of 10 per cent. Own-account construction work is deflated using a fixed-weighted index based on the Survey of Employment, Payroll and Hours (SEPH) for earnings in the construction industry, materials prices based on the Industrial Products Price Index, and overhead costs based on various prices indexes. Non-residential building construction made up 17.32 per cent of total construction industry value added in 2003.

Engineering Construction

Engineering construction is deflated in three components. The first two are highway construction and railway construction. A specific input-cost based deflator is used to deflate each. The remaining component of engineering construction is also deflated using a different input-cost based deflator. These deflators are based on a composite of wage, materials and overhead costs. The weights accorded to each of the three components were derived from the 1997 Input-Output tables. The wages component is based on the SEPH. These prices are not output prices, as noted in Table 3. The materials component is based on the Industrial Products Price Index (IPPI). The overhead costs component is based on a mix of average weekly earnings indexes and consumer price indexes. Engineering construction accounted for 28.11 per cent of total construction value added in 2003. Almost all of this output was deflated using input-cost indexes.

Repair Construction

Repair construction is deflated using the same cost index that is used to deflate residential renovations. Repair construction made up 19.39 per cent of total construction industry value added in 2003.

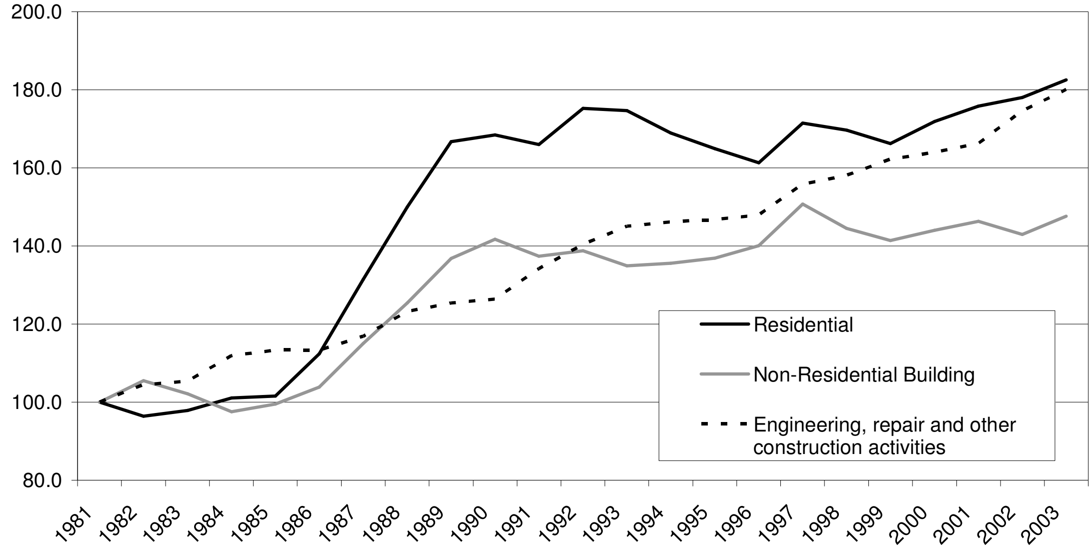
Are Input-Cost Based Deflators Biased Upward?

The previous section described how approximately 60 per cent[17] of value added in the construction industry in Canada is deflated using input-cost based deflators. Given the known problems with input cost indexes, it seems reasonable to hypothesize that a significant proportion of construction industry value added is being over-deflated, and, therefore, real output is being underestimated. This section will examine the evidence that is available to support (or refute) this hypothesis.

If input-cost based deflators used in the construction industry had an upward bias, we would expect to see a more rapid rate of growth in those deflators when compared with deflators based on output price indexes *ceteris paribus*. As was seen in the previous section, the deflators used by Statistics Canada to deflate the nominal value of gross output in the engineering , repair and other construction activities sub-industries are based entirely on input cost indexes. On the other hand, the deflator used to deflate non-residential building construction gross output is almost entirely based on output price indexes. The implicit deflator for engineering, repair and other construction activities, which is input-cost based, does increase much more rapidly, on average at 2.71 per cent annually between 1981 and 2003, than the implicit deflator for non-residential construction, which increased at 1.78 per cent annually (Chart 17). This finding is consistent with the hypothesis that the input-cost based deflators are biased upward.

[17] Based on 2003 figures. See Table 3.

Chart 17: Implicit Deflators for Residential, Non-Residential and Engineering and Repair Construction, 1981-2003



Source: Statistics Canada CANSIM Tables 379-0023 and 379-0017.

Compound Annual Growth Rates: 1981-2003
Residential Construction: 2.77%
Non-Residential Construction: 1.78%
Engineering, repair and other construction activities: 2.71%

What might be the impact of this potential bias on the total growth rate and levels of productivity in the construction industry? There is a difference of 0.93 percentage points between the average rates of growth of the implicit deflator for engineering, repair and construction activities, which is based almost entirely on input cost indexes, and the implicit deflator for non-residential building construction, which is based almost entirely on output price indexes. Let us assume that the implicit deflator for engineering, repair and other construction activities has risen more quickly than it would have if it were based on output price indexes. Therefore, this increase over-deflates output in engineering, repair and other construction activities. Then the deflator used to deflate non-residential building construction, which is based almost entirely on the Non-Residential Building Construction Price Index, could be applied to engineering, repair and other construction activities to provide a more accurate measure of productivity growth.

Let us conduct a brief experiment to see the impact of a change in the use of deflators. First we will calculate the implicit deflator for total construction as a weighted average of the deflators and output weights of the main component sub-industries (Equation (1)):

(1) Total construction implicit deflator (1981-2003) (2003 output weights)
=
(Output weight of residential construction)*(implicit deflator growth rate for residential construction)
+

(Output weight of non-residential building construction)*(implicit deflator growth rate for non-residential building construction)
+
(Output weight of engineering, repair and other construction activities)*(implicit deflator growth rate for engineering, repair and other construction activities)

= (0.3387)*(2.77) + (0.1732)*(1.78) + (0.4750)*(2.71)

= 2.53

Therefore, we will assume that the growth rate of the implicit deflator for total construction is 2.53 per cent per year. If we now replace the implicit deflator growth rate for engineering, repair and other construction activities with that of non-residential building construction, and recalculate equation (1) we get

(2) Total construction implicit deflator (1981-2003) (2003 output weights)

= (0.3387)*(2.77) + (0.1732)*(1.78) + (0.4750)*(1.78)

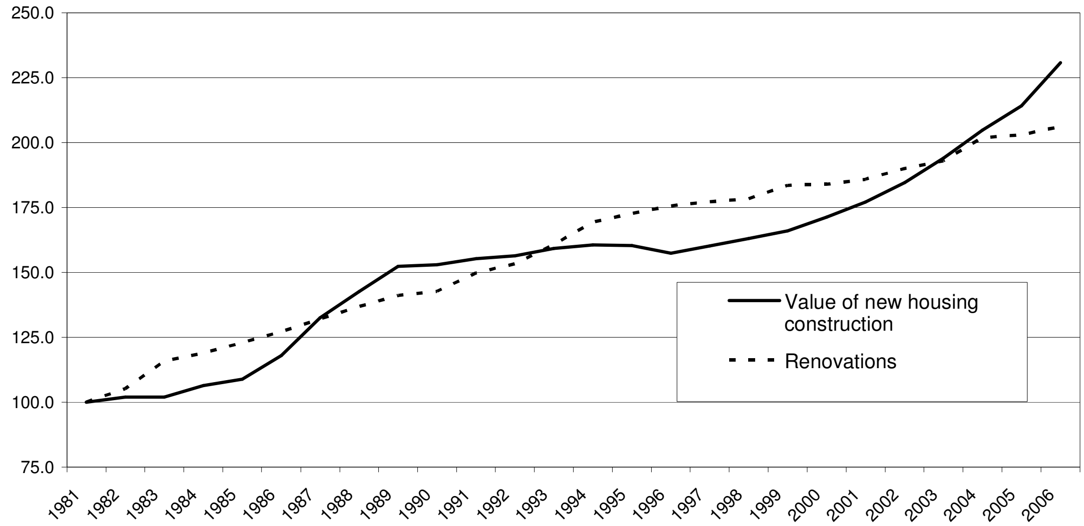
= 2.09

Equation (2) shows that a 0.44 percentage point decrease in the average growth rate for the overall construction deflator would result from a downward adjustment to the implicit deflator for engineering, repair and other construction activities. How would this adjustment impact productivity growth rates? The growth rate of productivity in the overall business sector between 1981 and 2006 was 1.46 per cent. The productivity growth rate in the construction industry was 0.53 per cent. The difference between the two was 0.93 percentage points. As an upper bound estimate of possible over-deflation of construction industry output, 0.44 points (47 percent) of this gap could be explained. If this situation were true, then construction industry productivity growth would have averaged 0.97 per cent per year rather than 0.53 per cent.

This estimate of measurement error assumes that changes in output prices for engineering and repair construction can be reasonably proxied by changes in output prices in non-residential building construction. The paper does not argue that these assumptions are valid. Therefore, the estimate of the upper bound of measurement error should be seen as suggestive and as an order-of-magnitude only.

What, however, is to be made of the 2.77 per cent annual growth rate in the implicit deflator for residential construction. Given that approximately two-thirds of value added in residential construction is deflated using output price indexes, why has the implicit deflator shown more rapid growth than the input-cost based deflator used in engineering, repair and other construction activities? Could it be that the input-cost based deflator used to deflate the renovations component of residential construction is biased upward? The evidence suggests that this is not the case (Chart 18). In fact the implicit deflator for the value of new housing rose slightly more rapidly, at 3.40 per cent per year, than the implicit deflator for renovations, which rose at 2.94 per cent per year.

Chart 18: Implicit Deflators for the Value of New Housing Construction and the for Renovations, 1981-2006, Canada



Compound Annual Growth Rates: 1981-2006
Value of new housing construction: 3.40%
Renovations: 2.94%

Source: Statistics Canada CANSIM Table 380-0010.

There are two observations that can be made about the relative paths taken by the output-price and input-cost based deflators. The first note is that in both the case of the implicit deflator for renovations (Chart 18) and the implicit deflator for engineering, repair and other construction activities (Chart 17), the growth pattern tended to be less variable than the growth paths of the deflators based on output prices. This phenomenon is the result of input costs generally being more stable than output prices. Indeed, input cost indexes tend almost never to fall. The second point of note is that the implicit deflators for residential and non-residential building construction increased greatly between 1985 and 1990, and then only increased slightly between 1990 and 2003 (Chart 17). At the same time, the implicit deflator for engineering, repair and other construction activities steadily increased throughout the 1980s and 1990s.

While there is some evidence that input-cost based deflators are overstating the rise in real value added in the construction industry in Canada, the evidence available is conflicting. While the implicit deflator for engineering, repair and other construction activities, based on input cost indexes, grow significantly faster than the output-price-index based implicit deflator for non-residential building construction, the input-cost-index based implicit deflator for renovations grows slightly less rapidly than implicit deflator for new housing, which is based almost entirely on output price indexes.

Is the Use of Prework Affecting Productivity Measurement in the Construction Industry?

This section will examine the impact of pre-work on productivity measurement in the construction industry. It will first clarify the terminology associated with prework as used in the study. It will then offer two explanations for why prework may not be affecting productivity measurement in the construction industry.

Terminology

Unfortunately, there appears to be a lack of clarity about the precise definition of prework and of its components: modularization, prefabrication, and preassembly.[18] Therefore, it is worth briefly clarifying what is meant by these terms as used in this study. Following Haas *et al.* (2000), a study completed by the Center for Construction Industry Studies at the University of Texas at Austin, the components of prework are:

> *Modularization:* construction of a complete system away from the job site that is then transported to the site. Modules may be too large to transport in one piece, and, therefore, may need to be broken down into smaller pieces for transport.
>
> *Prefabrication:* Tatum *et al.* (1987) define prefabrication as "a manufacturing process, generally taking place at a specialized facility, in which materials are joined to form a component part of a final installation." Haas *et al.* (2000: 3-4) add that prefabrication "normally involves one skill or trade, such as electrical, piping, or rebar" and that "any component that is manufactured offsite and is not a complete system can be considered prefabricated."
>
> *Preassembly:* Preassembly is a combination of prefabrication and modularization. It involves the assembly of materials and prefabricated components at the jobsite or somewhere else. Preassembly often involves the work of numerous trades and usually only involves part of a system. Preassembled work is installed in a manner similar to the installation of modules. (Haas *et al.,* 2000: 4)

Given this clarification of the definition of prework, there are two reasons why it appears that prework is not likely an important factor leading to the mismeasurement of construction industry productivity growth.

Prework and Productivity: Are the Productivity Gains Showing Up in Construction or Manufacturing?

[18] The term *industrialization* has also been used in reference to pre-work, for example Finn (1992), but following Haas *et al.* (2000) this study does not use that term.

The first reason why prework may not impact construction productivity is that an increase in prework does not necessarily mean that labour productivity growth in the construction industry will increase. This seemingly counter-intuitive situation arises because of the way production activities are allocated on an industry basis by Statistics Canada. Most importantly, prework, as defined above, with the exception of some components of preassembly, does not occur in the construction industry as defined by Statistics Canada. Under the classification system used for industries[19] *establishments* are grouped into *industries* based on the similarity of their production methods. An establishment is defined by Statistics Canada as

> the most homogeneous unit of production for which the business maintains accounting records from which it is possible to assemble all the data elements required to compile the full structure of the gross value of production (total sales or shipments, and inventories), the cost of materials and services, and labour and capital used in production… An establishment comprises at least one location but it can also be composed of many.[20]

For instance, the manufacturing industry is composed of all those establishments that use a manufacturing-type process to produce an output. So-called modularization and prefabrication shops fall into the manufacturing industry by this definition. As a result, any productivity gains associated with the shift in work from the job site to the prework shops are not captured as improvements in construction industry productivity, although they may reduce total time needed to complete a project.[21]

One possibility for why the perceptions of industry practitioners (see Part III) and the official statistics diverge could be that the industry and the statisticians are using different definitions of productivity, different definitions of the construction industry, or different definitions of both concepts.

Because productivity is usually calculated as value added per hour worked, even if there are significant productivity gains associated with a shift to prework, these productivity gains will not appear in the construction industry; they will appear in the total economy. The productivity gains result from the shifting of inputs (labour) from an industry with lower productivity levels (construction) to an industry with higher productivity (manufacturing). The gains in productivity do not take place within any one industry. The example provided in Appendix III illustrates one of the two reasons why an important shift to prework, which could be enhancing the overall productivity of the economy, may not be affecting productivity in the construction industry (or even the manufacturing sector).

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[19] Statistics Canada currently uses the North American Industry Classification System (NAICS), pronounced "nakes." More information is available on the Statistics Canada website at http://www.statcan.ca/english/Subjects/Standard/naics/2002/naics02-index.htm

[20] Statistics Canada website, NAICS Introduction: http://www.statcan.ca/english/Subjects/Standard/naics/2002/naics02-intro.htm

[21] See Appendix III for an example of how prework fails to increase construction industry productivity.

Is Prework Really Becoming More Important in the Construction Industry?

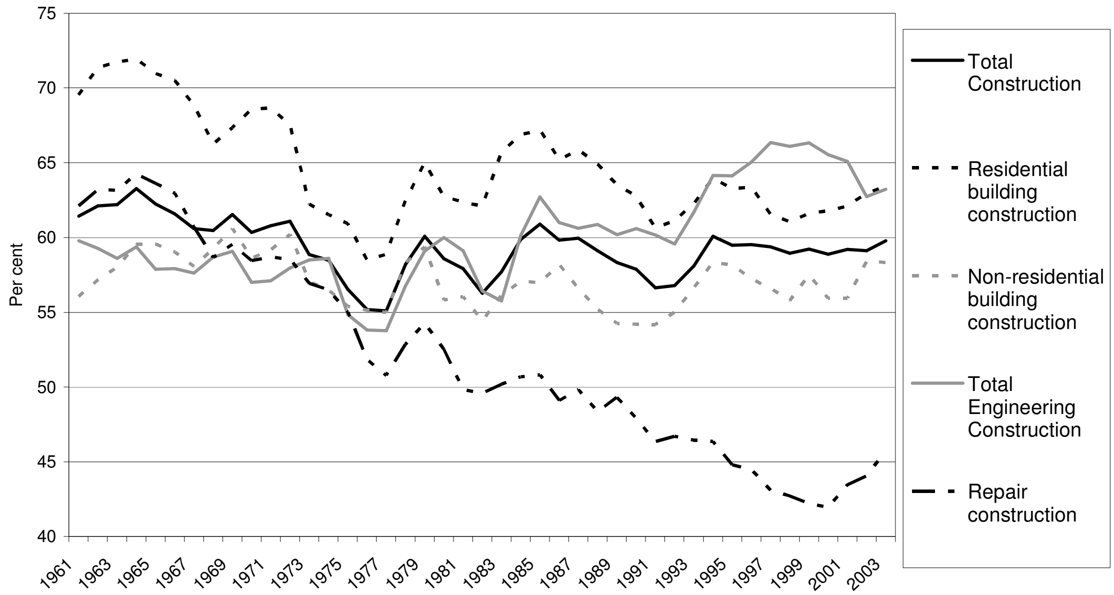
Prework is no doubt an important aspect of the construction industry, but notwithstanding the opinions and perceptions of all practitioners interviewed (see Part III), there is no statistical evidence to suggest that prework is becoming a more important input to the construction industry.

We have already seen that practitioners believe increasing prework to be an important trend in the construction industry. What is the statistical evidence for this trend? Given the growth of the construction industry, it is certainly true that prework has increased in absolute terms. If prefabricated and modularized inputs were increasingly important in construction, then one would expect to see an increasing proportion of the value of intermediate goods to the value of gross output in the construction industry over time. Intermediate goods are the inputs to the construction industry purchased from other industries, like manufacturing or wholesale. If inputs are increasingly prefabricated in the manufacturing industry and then sold to the construction industry, then, as the example in Appendix III (Table 1, bottom panel) shows, we would expect to see a decline in proportion of construction industry value added to construction industry gross output. In other words, we would expect to see the share of the value of intermediate goods in gross output to rise in the construction industry.

The proportion of the value of intermediate goods to the value of gross output in the construction industry as a whole has remained remarkably stable at around 60 per cent between 1961 and 2003 (Chart 15). Within the construction industry, there has been a downward trend in residential and repair construction and an upward trend in the other two components. A similar stability is observed for non-residential building construction. Between 1961 and 2003 the proportion for engineering construction was also stable over the entire period, but it did fall between 1961 and the late 1970s then increase from the late 1970s to the late 1990s, consistent with increasing prefabrication and modularization. Repair construction exhibited a surprising and steady downward trend over the period, consistent with decreased prefabrication and modularization. Finally, residential construction exhibited a decline in the ratio of the value of intermediate goods to the value of gross output, falling from a high of approximately 70 per cent in 1961 to 63 per cent in 2003.

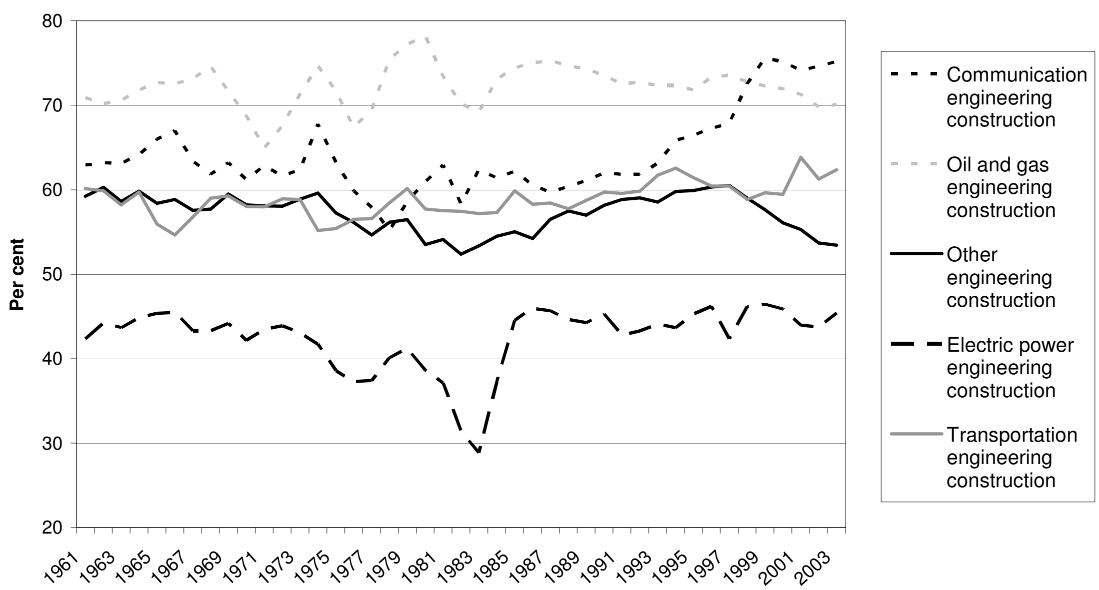
When engineering construction is examined in more detail (Chart 16), we can see that the ratio of the value of intermediate inputs to the value of gross output has remained fairly constant, even if there have been a few notable short-term fluctuations. Communication engineering construction is a notable exception with an increase from 60 per cent in 1987 to almost 75 per cent in 2000.

Chart 15: Value of Intermediate Goods as a Proportion of Gross Output, major construction sub-industries, per cent, Canada, 1961-2003



Source: Compiled by the CSLS from Statistics Canada CANSIM Tables 379-0023 and 381-0009.

Chart 16: Value of Intermediate Goods as a Proportion of Gross Output, engineering construction sub-industries, per cent, Canada, 1961-2003



Source: Compiled by the CSLS from Statistics Canada CANSIM Tables 379-0023 and 381-0009.

Given strong anecdotal evidence of increasing prefabrication and modularization in the oil and gas engineering construction sub-industry in particular, these results are surprising. One possibility is that perceptions of increasing prefabrication and modularization reflect an increase in the absolute level of these activities. However, given a general expansion of the gross output of the oil and gas engineering construction sub-industry, these activities have not actually increased in value relative to gross output. Another important factor to take into account is that the data show that intermediate inputs have always been relatively more important in oil and gas engineering construction than in other engineering construction sub-industries. Communications engineering construction is a recent exception. This higher share of intermediate goods in gross output is consistent with a higher level of prefabrication and modularization. More research will be required to determine whether or not this hypothesis is supported empirically.

There are two possible reasons why prework may not be affecting the measurement of construction industry productivity. First, productivity gains associated with prework are not accruing to the construction industry. Second, there is little statistical evidence to support the observation that prefabrication and modularization are relatively more important in the construction industry today than in the past. This finding is surprising and more research is needed to determine why statistics do not show a relative increase in these activities, while practitioners universally claim that such an increase is occurring.

Part V: Synthesis of the Discussion and Conclusion

This report has provided a thorough discussion of issues related to the measurement of labour productivity in the construction sector in Canada. The motivation for the study has been to ascertain if measurement problems, particularly the mismeasurement (underestimation) of real output, can account for the weak labour productivity growth (0.53 per cent per year) experienced in the construction industry in this country over the last quarter century (1981-2006). Much evidence has come to the fore and the purpose of this part of the report is to synthesize and summarize this evidence. The first section puts forth the evidence or arguments that support the view that measurement problems can indeed explain the poor productivity growth in the construction industry. The second section assesses the arguments that cast doubt on the mismeasurement hypothesis. The final section concludes.

Evidence Supporting the Mismeasurement Hypothesis

At least five pieces of evidence suggest that official estimates of productivity growth may underestimate true labour productivity growth in the construction industry in Canada

Use of input-cost deflators

By far the strongest evidence relates to the use of input-cost based deflators instead of output-price based deflators to deflate the nominal value of output to obtain real output in the construction sector. Because of productivity gains, output prices tend to increase at a somewhat slower pace than input prices. This means that the use of the faster rising input-cost based deflators, everything else being equal, tends to produce lower real output and hence lower productivity growth than the use of output price deflators. As discussed in Part II of the report, the use of input-cost based deflators has been identified in the literature as an important explanation for the poor productivity growth in the US construction industry.

There is evidence in Canada that the input cost indexes used in the construction sector have risen faster than output price indexes. For example, the input-cost based deflator, which is used to deflate nominal output in engineering construction and repair, advanced at a 2.71 per cent average annual rate over the 1981-2003 period. In contrast, the deflator for the nominal output of non-residential building construction, which is largely based on an output price index, advanced at an average annual rate of only 1.78 per cent, a difference of 0.93 percentage points.

If it were the case that true price movements in engineering construction were similar to those in the non-residential building construction, then the true real output and productivity developments in the sector could be proxied by deflating nominal output by the non-residential building deflator. While this report does not argue that this assumption is necessarily valid, such a step would increase real output and productivity growth by 0.93 per cent per year over the period in the engineering and repair sub-industry, a significant boost. Given that engineering construction, repair and other construction activities represents about 48 per cent of total construction GDP, this in turn would increase output per hour growth in the overall construction sector by 0.44 percentage points per year, from around 0.53 per cent to 0.97 per cent. Thus an upper-bound estimate of the role of measurement error would be 0.44 percentage points, a significant number over such a long period. This estimate should be seen as suggestive and as an order-of-magnitude only.

Strong construction productivity gains in other countries

This report has noted that it is not inevitable that construction productivity growth be weak. The section on international productivity trends showed that labour productivity growth in the construction sector in many countries was above 1.5 per cent per year over the 1979-2003 period. The UK construction industry, for example, experienced output per hour growth of 1.9 per cent per year. This situation may suggest that, if properly measured, construction productivity growth can be robust and that Canada's poor productivity performance may reflect mismeasurement. Of course, other factors might also account for faster construction productivity growth in other countries so the use of differences in international productivity performance to support the mismeasurement hypothesis may be suspect.

Significant task-based productivity gains

Both the literature on productivity measurement in the construction industry and the construction practitioners interviewed for this report provided strong evidence that on a task basis there have been significant productivity gains in construction. Given the large number of construction tasks that many argue experienced gains, one might have expected that this would have translated into stronger productivity growth at the level of the industry and that the failure of such gains to appear is due to the inability of the statistical system to capture them because of measurement problems.

The counter-argument is that the number of tasks where productivity gains have been significant may indeed not have been that large, and therefore one would not expect a major impact of the overall rate of productivity growth in the construction industry. Moreover, at least one practitioner noted that productivity growth could be slow due to a lack of significant improvement in management and organization coupled with the increasing complexity of projects.

Failure to adjust construction output for quality improvements

It is recognized that price indices should be adjusted to take account of quality improvements, and that such adjustments can lead to much lower price increases and larger real output increases. This has been the case in the computer industry where massive quality improvements in computers have resulted in plummeting quality-adjusted prices and soaring real output. While the quality improvements in the output of the construction industry are certainly much less than in the computer industry, the construction industry practitioners interviewed for this study identified a significant number of quality improvement, such as more energy efficient buildings and lower maintenance structures. If Statistics Canada has not made sufficient downward adjustment in construction price indexes to reflect these quality improvements, then real output and productivity growth may be underestimated.

Strong growth in capital-labour ratio in construction

A key driver of labour productivity is the increase in the capital with which each worker works. The rate of growth of the capital-labour ratio in the construction industry in Canada has been strong, averaging 2.57 per cent per year over the 1987-2004 period. Yet this increased capital intensity of production of the sector has not translated into labour productivity gains, which is surprising and a different result from that found in other sectors. This may suggest that measurement error is at play.

Evidence Not Supporting the Mismeasurement Hypothesis

Evidence not supporting the mismeasurement hypothesis includes weak construction productivity growth observed in other countries, rapid productivity growth in earlier periods, large provincial differences in construction productivity growth, the lack of evidence of a failure to capture the underground economy, and the lack of an effect of prework on construction productivity.

Weak productivity growth in other countries

As shown earlier in the report, a large number of countries experienced very weak labour productivity growth in the construction industry over the 1979-2003 period. For example, the United States saw an average annual decline of 0.8 per cent in output per hour per year, and both Japan and Germany experienced slightly negative productivity growth in their construction industries. Of course, measurement problems might account for the dismal construction sector productivity performance in these countries. But to the degree that the statistical systems of these countries are better at capturing true productivity gains than the Canadian statistical system, this situation may be due to the reality that productivity growth in construction is fundamentally slower than in other sectors because of the labour-intensive nature of many construction tasks which are not amenable to mechanization.

Earlier periods of rapid construction productivity growth in Canada

Labour productivity in the construction industry in Canada advanced at the phenomenal rate of 5 per cent per years between 1974 and 1983. This suggests that our statistical system was fully capable of capturing construction productivity gains in the past and the fact that since 1983 it has recorded only weak gains suggests that they may just not be there to be recorded. Of course, measurement problems could have been at play in both periods. At the same time, the evidence suggests that Statistics Canada did alter its measurement techniques for construction prices in the 1980s and 1990s. While outside the scope of this article, more research is required to determine how changes over time in the measurement techniques used by Statistics Canada have affected productivity estimates for the construction industry.

Large provincial differences in construction productivity growth

As noted in Part I, estimates of construction productivity by province show very large differences. These differences suggest that factors other than measurement problems may be at play in explaining construction productivity growth. Of course, both measurement problems and other factors may be at work. Differences across provinces are not inconsistent with measurement problems.

Lack of evidence of a failure to capture the underground economy

It is widely recognized that much construction activity is not reported to the taxation authorities. But this does not mean that these transactions are not included through imputations in the estimates of nominal output for the construction industry produced by Statistics Canada. Indeed, our detailed analysis of the procedures used by Statistics Canada to estimate the nominal output of the industry suggests that the lion's share of underground activity is accounted for and that nominal output and hence real output is not underestimated. However, because of the clandestine nature of underground activity, one cannot say with full certainly that this is the case.

The lack of effect of prework on construction productivity

The report showed that the greater use of prework, defined as modularization, prefabrication and preassembly, in the construction industry, while resulting in productivity gains in terms of overall labour requirements for construction projects, has no *a priori* effect on the output per hour in the construction industry itself. In addition, the stability of the ratio of current dollar intermediate goods to gross output suggests that the relative importance of prework has not been increasing over time in Canada.

Conclusion

This article makes a case that measurement error may account for much of the weakness in labour productivity growth in the construction industry in Canada over the last quarter century. It is argued that the use by Statistics Canada of input-cost based deflators in the deflation of the nominal value of output in a number of construction sub-industries introduces a significant downward bias into productivity estimates. A ballpark estimate of the upper bound of this bias would be 0.44 percentage points per year over the 1981-2006 period. This would raise output per hour growth in the construction sector from 0.53 per cent to 0.97 per cent and would eliminate about one-half of the gap in labour productivity growth between the construction industry and the overall business sector. It is important to stress that these estimates should be seen as suggestive and as an order-of-magnitude only.

Recommendation for Future Research

This study raises many opportunities for further research in construction productivity.

- This study noted the exceptionally high level of labour productivity in the construction industry in the province of Quebec in 2003 (Chart 6). What could explain this high productivity level relative to other provinces?

The international comparison of construction industry productivity across developed countries revealed many interesting possibilities for future research (Chart 14):

- Why has productivity growth in the construction industry in the United States declined at an annual rate of 0.84 per cent between 1979 and 2003? Could measurement error be involved?

- Why has productivity growth in the United Kingdom averaged 1.92 per cent over the 1979-2003 period? If measurement issues do not account for this performance, then what could Canada learn from this strong productivity growth?

Another area that could be fruitfully exploited for future research is task-based productivity. While the construction industry in the United States has conducted extensive research and gathered considerable data on task-based productivity, such initiatives in Canada have yet to be undertaken. This study has noted that task-based productivity measurement cannot capture all aspects of productivity growth, since some tasks are difficult or impossible to quantify. However, task-based productivity growth measurement is of great interest to the industry, because it offers transparent and concrete statistical evidence of progress or declines in the productivity of specific construction activities and can, therefore, suggest specific policies or actions to improve productivity in a way that aggregate productivity measurement cannot. As a first research step, data could be gathered in a systematic and rigorous fashion from construction firms and contractors across Canada, and a possible research question could be

- What are the trends in task-based productivity in Canada, by construction sub-industries and by provinces, and even by census metropolitan areas?

Bibliography

Allen, Steven G. (1985), "Why Construction Industry Productivity is Declining," Working Paper no. 1555, NBER, February.

Allen, Steven G. (1989) "Why Construction Industry Productivity is Declining: Reply," *The Review of Economics and Statistics*, Vol. 71, No. 3., pp. 547-549, August.

Allmon E, Carl Haas, John Borcherding and Paul Goodrum (2000) "US construction labour productivity trends, 1970-1998", Journal of Construction Engineering and Management, Volume 126, pp. 97-104, March / April.

Beckstead, Desmond, and Jean-Pierre Maynard (2001) "Appendix 2 – Industrial Detail for Productivity Measures and Related Variables," in *Productivity Growth in Canada.* Statistics Canada Catalogue no. 15-204-XIE, January 2001, pp. 177-183

Building Futures Council (2005) "Measuring Productivity and Evaluating Innovation in the U.S. Construction Industry," May.

Cattell, K. Flanagan, R. and Jewell, C. (2004) "Competitiveness and productivity in the construction industry: The importance of definitions," CIDB 2nd Postgraduate Student Conference Proceedings, Cape Town, 10 - 12 October, pp 25-35.

Centre for the Study of Living Standards (2001) "Productivity Trends in the Construction Sector in Canada," report prepared for Canada Mortgage and Housing Corporation, CSLS Research Report 2001-3, November.

Dacy, Douglas C. (1965) "Productivity and Price Trends in Construction Since 1947," *The Review of Economics and Statistics*, Volume 47, No. 4 pp. 406-411.

Dubois, Anna and Lars-Erik Gadde (2002) "The construction industry as a loosely coupled system: implications for productivity and innovation" *Construction Management and Economics,* Volume 20, pp.621-631.

Eurostat and OECD (2001) "Sources and Methods: Construction Price Indices," October.

Finn, D.W. (1992) "Towards Industrialized Construction," *Construction Canada*, Vol. 34, May.

Flanagan, R., K. Cattell and C. Jewell (2005) "Moving from construction productivity to construction competitiveness: measuring value not output"

Goodrum P, Carl Haas and Robert Glover (2002) "The divergence in aggregate and activity estimates of US construction productivity," Construction Management and Economics, Volume 20, pp. 415-423, July.

Goodrum P. and Carl Haas (2002) “Partial factor productivity and equipment technology change at activity level in US construction industry,” Journal of Construction Engineering and Management, Volume 128, pp. 463-472, Nov / Dec.

Gordon, Robert J. (1968) “A New View of Real Investment in Structures, 1919-1966,” *Review of Economics and Statistics,* pp. 417-428,

Gullickson, William and Michael J. Harper. (2002) “Bias in aggregate productivity trends revisited,” *Monthly Labor Review,* pp. 32-40, March.

Harchaoui, Tarek M., Mustapha Kaci, and Jean-Pierre Maynard (2001) “Appendix 1 – The Statistics Canada Productivity Program: Concepts and Methods,” in *Productivity Growth in Canada,* Statistics Canada Catalogue no. 15-204-XIE, January, pp. 143-176.

Harrison, Peter (2006) “Can Measurement Error Explain the Weakness of Productivity Growth in the Canadian Construction Industry?” *International Productivity Monitor*, no. 14, Spring, pp. 53-70.

Harrison, Peter (2006) “L’erreur de Mesure peut-elle Expliquer la Faiblesse de la Croissance de la Productivité dan l’Industrie de la Construction au Canada?” *Observateur International de la Productivité*, no.14, Printemps, pp. 53-70.

Haskell, Preston H., (2004) “Construction Industry Productivity: Its History and Future Direction,” The Haskell Company, December.

Haas, Carl T., James T. O’Connor, Richard L. Tucker, Jason A. Eickmanm, Walter R. Fagerlund. (2000) “Prefabrication and Preassembly Trends and Effects on the Construction Workforce.” Austin: University of Texas at Austin, Center for Construction Industry Studies, Report no. 14.

Hendrickson, Chris (2005) “Discussion of ‘Is Construction Labor Productivity Really Declining?’ by Eddy M. Rojas and Peerapong Aramvareekul,” *Journal of Construction Engineering and Management,* pp. 269-270, February.

Ive, Graham, Stephen Gruneberg, Jim Meikle and David Crosthwaite. (2004) “Measuring the Competitiveness of the UK Construction Industry,” *Construction Economics and Statistics,* Volume 1, September.

Katsanis, Constantine J. (2003) “System dynamics modelling for a decision support system for assessing construction productivity” 5th Construction Specialty Conference of the Canadian Society for Civil Engineering.

Mohammadian, Rasool and Stan Seymour (1994) “Construction Price Index Methodology,” Capital Expenditures Prices Section, Prices Division, Statistics Canada.

Mohammadian, Rasool and Stan Seymour (1997) "An Analysis of Some Construction Price Index Methodologies," Prices Division Analytical Series, cat. no. 62F0014MIB - No. 2, Statistics Canada, April.

Mohammadian, Rasool and Lloyd Waugh (1997) "Productivity Adjustment in Construction Price Indexes," Prices Division Analytical Series, cat. no. 62F0014MIB - No. 3, Statistics Canada, April.

O'Grady, John, Greg Lambert and the ARA Consulting Group (1998) "The Underground Economy in Ontario's Construction Industry: Estimates of Its Size and the Revenue Losses to Government and the WISB", prepared for the Ontario Construction Secretariat, November.

O'Grady, John, and Prism Economic Analysis (2001) "Estimates of Revenue Losses to Government as a result of Underground Practices in Ontario's Construction Industry", prepared for the Ontario Construction Secretariat, August.

Park, Hee-Sung, Stephen R. Thomas and Richard L. Tucker. (2005) "Benchmarking Construction Productivity." *Journal of Construction Engineering and Management,* Volume 131, pp. 772-778, July.

Pieper P. (1989) "Why Construction Productivity is Declining: Comment," *The Review of Economics and Statistics*, Vol. 71, No. 3., pp. 543-546, August.

Pieper, Paul (1989a) "Construction Price Statistics Revisited," in Dale W. Jorgenson and Ralph Landau (eds.) *Technology and Capital Formation* (Cambridge: MIT Press).

Pieper, Paul (1990) "The Measurement of Construction Prices: Retrospect and Prospect," in Ernst R. Berndt and Jack E. Triplett (eds.) *Fifty Years of Economic Measurement: The Jubilee of the Conference on Research in Income and Wealth* , National Bureau of Economic Research, Studies in Income and Wealth, Volume 54 (Chicago: University of Chicago Press).

Rojas, Eddy M. and Peerapong Aramvareekul (2003) "Is Construction Labor Productivity Really Declining?" *Journal of Construction Engineering and Management*, Vol. 129, pp. 41-46, February.

Schreyer, Paul and Dirk Pilat (2001) "Measuring Productivity," Economic Studies no. 33, OECD, Second Quarter.

Sharpe, Andrew (2001) "Productivity Trends in the Construction Sector in Canada," *International Productivity Monitor*, Number Four, Fall pp. 54-67

Sharpe, Andrew (2002) "Productivity Concepts, Trends and Prospects: An Overview," in *Review of Economic Performance and Social Progress, Towards a Social Understanding*

Productivity, ed. Andrew Sharpe, France St-Hilaire and Keith Banting (Ottawa: Centre for the Study of Living Standards), pp. 31-56.

Statistics Canada (1994) "The Size of the Underground Economy in Canada," cat. 13-603.

Statistics Canada (2001a) *A Guide to Deflating the Input-Output Accounts: Sources and methods.* Statistics Canada Catalogue no. 15F0077GIE. System of National Accounts.

Statistics Canada (2001b) "Innovation, Advanced Technologies and Practices in the Construction and Related Industries: National Estimates," Science, Innovation and Electronic Information Division, February.

Statistics Canada (2002) *Gross Domestic Product by Industry – Sources and Methods,* Statistics Canada Catalogue no. 15-547-XIE.

Statistics Canada (2005) *Capital Expenditure Price Statistics, First Quarter 2005,* Statistics Canada Catalogue no. 62-007-XPB.

Stokes, H. Kemble (1981) "An Examination of the Productivity Decline in the Construction Industry," Review of Economics and Statistics, Volume 63, November, pp. 495-502.

Tatum, C.B., Vanegas, J. A., and Williams, J. M. (1987) "Constructability, Improvement Using Prefabrication, Preassembly, and Modularization," Construction Industry Institute, The University of Texas at Austin.

TD Economics (2005) "Who's to blame for Canada's productivity woes?" Topic Paper, June 15.

Teicholz P., Paul M. Goodrum and Carl T. Haas (2001) "U.S. Construction Labor Productivity Trends, 1970-1998," Journal of Construction Engineering and Management, Volume 127, pp. 427-429, Sep / Oct.

World Bank (2002) "Size and Measurement of the Informal Economy in 110 Countries around the World," by Friedrich Schneider. July.

Appendixes

Appendix I: Survey of Construction Industry Practitioners

List of Practitioners Surveyed

Neil Tidsbury
President
Construction Labour Relations – An Alberta Association
Calgary, Alberta

Derm Cain
Canadian Director
International Union of Operating Engineers
St. John’s, NFLD

Bob Blakely
Director of Canadian Affairs
Building and Construction Trades Department AFL-CIO
Ottawa, Ontario

Tom Brown
Senior Vice President Operations
Ledcor Alberta Limited
Edmonton, Alberta

Pat Dillon
Secretary Treasurer
Ontario Provincial Building Trades Council
Rexdale, Ontario

Pat Darrah
Executive Director
Saint John Construction Association
Saint John, NB

Paul Gravelle
National Coordinator, Education and Training
Canadian Home Builders’ Association
Ottawa, ON

[Duplicate of Survey Questionnaire]

Questionnaire for Industry Practitioners on Productivity Measurement in the Canadian Construction Industry

Name ____

Organization ____

Date and Time ____

1. According to official Statistics Canada productivity estimates, labour productivity in the construction sector, defined as output per hour worked, has advanced at only a 0.3 per cent average annual rate over the 1981-2005 period in Canada. This is less than one quarter the pace of labour productivity growth in the overall business sector productivity growth (1.3 per cent). Based on your knowledge of the sector, is this very poor productivity performance consistent with the productivity trends you have observed?

Yes_____

No_____

Comments

2. In contrast to the aggregate approach to productivity employed by statistical agencies, construction industry researchers attempt to measure the amount of labour time associated with discrete tasks in the construction industry, such as compaction, ceiling tile installation, and residential framing. This research shows significant productivity gains for many construction tasks. Is this finding of significant tasks-based productivity gains consistent with your experience in the sector?

Yes____

No____

Comments

3. Do you have any specific information on trends in labour requirements for specific tasks in the construction sector or on overall construction productivity growth at the firm or industry level?

4. One frequently heard explanation for the poor measured productivity performance is that significant output in the sector is underreported because of tax considerations. Statistics Canada argues that it adjusts reported construction sector revenues for underground activity, but the magnitude of the adjustment may be insufficient. Do you think there is significant underreporting of revenues in the construction industry?

   Yes____

   No____

   If so, do you think this phenomenon has grown over time. If possible, please provide a guestimate of the proportion of true revenues that may be underreported.

5. Another possible reason for the poor productivity performance of the construction sector is that prices indexes for the sector, which are use to deflate nominal or current dollar output to produce real or constant dollar output estimates, exhibit too large an increase, which reduces real output growth. It is sometimes argues that price statisticians are not making sufficient adjustment for improvements in the quality of the output of the sector, such as better energy efficiency, greater access for the disabled, use of more durable materials, etc. Can you provide any examples of improvements in the quality of the buildings and structures produced by the construction sector that may not have been taken into account in the estimation of the price of these buildings and structures?

6. The key driver of productivity advance is technological improvement, either embodied in new equipment (embodied technological change), or in the organization of production (disembodied technological change). If such improvements could be identified, then it is harder to substantiate the official estimates of poor productivity performance in the construction sector. Based on your experience, can you point to any major technological innovations in the production processes used in the construction industry in recent years that in principle should have considerably boosted labour productivity?

7. Increasing prefabrication and preassembly has been identified as an important trend in the construction industry in the United States In your experience, is this trend toward prefabrication and preassembly also taking place in Canada? Do you see any implications for productivity measurement?

Appendix II: How Do Input-Cost-Index-Based Deflators Over-Deflate Nominal Output?

In this Appendix we will consider two scenarios in which input-cost indexes will over-deflate nominal output relative to output-price indexes. The first scenario shows what happens when the mix of inputs used to construct a structure changes, while the index of input costs retains the base year weights. The second scenario in which an input-cost index based deflator can be problematic is in the face of improving labour productivity. Again, the reason for the problem is the same. If the weights assigned to input-cost index in the base year are not updated to reflect increasing labour productivity, then an input-cost-index based deflator will lead to downward-biased real output estimates relative to an output-price-index based deflator.[22]

Scenario I: Bias Caused by Changing Input Mix

It is a fact that over time the same structure can be built using different combinations of inputs. A builder may change the mix of the inputs for a variety of reasons; one of the most important is technological change. In this example technological changes take the form of a reduction in the requirement for lumber used to build a roof truss, perhaps because of a switch from traditional lumber to engineered lumber. At the same time the amount of labour required to build a roof truss is unchanged. Since labour input and the output remain the same, namely one hour for one roof truss, labour productivity is constant.[23]

Another process underway in this example is a gradual increase in the price of inputs. This phenomenon, called inflation, is well known to the general public and the construction industry. In this case, labour costs per hour increase from $18.00 in Year 1 to $21.50 in Year 5, implying a 3.62 per cent average annual increase. Lumber prices also increase over time, from $34.00 per board foot in Year 1 to $46.00 per board foot in Year 5, inflation at a rate of 6.23 per cent per year.

The input cost index that appears in Table 1 captures the increase in both the price of lumber and the price of labour. However, it does so by assuming that the proportion of lumber to labour remains constant over the five years (2.3 board feet of lumber and one hour of labour). This assumption is clearly false, since while one hour of labour is always required, the amount of lumber required falls from 2.3 board feet in Year 1 to 2.0 board feet in Year 5. As noted above, this changing mix of inputs, which is not captured in the input-cost index, is responsible for the bias that this index will impart to real output estimates.

[22] If the weights of an input cost index were updated frequently that index would closely approximate an output price index.
[23] For simplicity, let us assume that the truss produced with engineered lumber is of identical quality to that produced with traditional lumber.

Table 1: Building a Roof Truss - Scenario I: Changing Input Mix									
Year	Inputs					Value of Inputs = Value of Outputs	Output price index	Real Value of Output in Year 1 dollars	
	Labour used (hours)	Labour Cost per Hour	Lumber used (board feet)	Cost per board-foot	Input-cost index			Based on input-cost index	Based on output-price index
Year 1	1.0	$18.00	2.3	$34.00	100.0	$96.20	100.0	$96.20	$96.20
Year 2	1.0	$19.00	2.2	$37.00	108.2	$100.40	104.4	$92.78	$96.20
Year 3	1.0	$20.00	2.1	$39.00	114.0	$101.90	105.9	$89.36	$96.20
Year 4	1.0	$21.00	2.1	$41.00	119.9	$107.10	111.3	$89.36	$96.20
Year 5	1.0	$21.50	2.0	$46.00	132.3	$113.50	118.0	$85.77	$96.20
Annual Rate of Change (per cent)	0.00	3.62	-2.76	6.23	**5.76**	**3.36**		**-2.27**	**0.00**

How does this bias arise? The input-cost index increases by an average of 5.76 per cent per year. This increase overestimates the true increase in the cost of a roof truss, since in reality less lumber is being used over time. The cost of building the truss has only increased at an average annual rate of 3.36 per cent over the five-year period. If we assume that profit margins are constant (and in this case are set equal to zero)[24] and markets are reasonably competitive, then the price of a truss in the market will also have risen by 3.36 per cent per year, or from $96.20 to $113.50.

It is important to keep in mind that real output, that is the actual physical thing being made, is the same in Year 5 as it was in Year 1. Only the price of the output has changed. When economists wish to measure change in real output they must adjust for the price change caused by inflation. In this example, there are two possible ways to make this adjustment. The best procedure would be to track the price of a roof truss over time and use the resulting price index to adjust downward the nominal price of the roof truss.

How does such a process work? First, an output-price index is created based on the nominal price of output (Table 1). In order to get the real value of output, which in this example is always the same, $96.20, since the output is always one truss, the nominal output in a given year is divided by the price index value for that year, then multiplied by 100. The result of this procedure is a real value of output that does not change between Year 1 and Year 5.

Unfortunately, in the real world accurate input-cost data is much easier to collect than accurate output-price data. As a result, output-price data is not always available for certain construction outputs. One key reason for this lack of availability may be a lack of resources or priority in statistical agencies. A second-best option for deflating nominal output is to use an input-cost index. We have already seen that an input cost index overstates the increase in the price of an output, like a truss, relative to an output-price index. What happens when an input-cost index is used to deflate nominal output? The result is over-deflation. The estimates of real output rise too slowly relative to reality. In

[24] This is a common assumption. All results above would hold equally regardless of the level of profit.

this example, the use of an input cost index in fact leads to estimates that show a decrease in real output. As noted, since *one* truss is always the output, real output has not declined over time. The input cost index has led us to inaccurately conclude that labour productivity has fallen when in fact it has not.

Scenario II: Bias Caused by Increasing Labour Productivity

This story is very similar to that told above. The difference is that labour productivity is increasing while other inputs used are always the same (2.0 board feet of lumber). Here the number of labour hours required to produce a roof truss falls from 1.3 in Year 1 to 1.0 in Year 5, an improvement in labour productivity of 5.4 per cent per year. One possible explanation for such an improvement could be the gradual replacement of traditional tools with pneumatic tools.

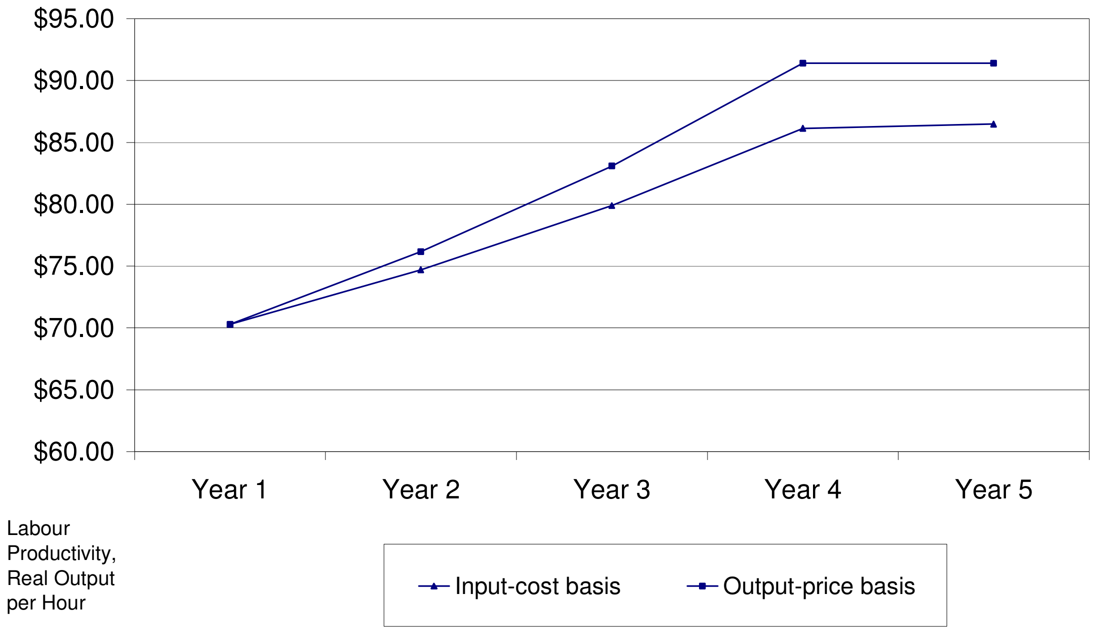
As was the case in Scenario I, the input-cost index does not account for the reduction in labour that has occurred. It rises by 5.59 per cent per year. On the other hand, the output price only rises by 4.43 per cent per year, because less labour is being used, even though the price per hour of labour and the price per board foot of lumber are steadily increasing.

Table 2: Building a Roof Truss - Scenario II: Increasing Labour Productivity

Year	Inputs					Value of Inputs = Value of Outputs	Output price index	Real Value of Output in Year 1 dollars	
	Labour used (hours)	Labour Cost per Hour	Lumber used (board feet)	Cost per board-foot	Input-cost index			Based on input-cost index	Based on output-price index
Year 1	1.3	$18.00	2.0	$34.00	100.0	$91.40	100.0	$91.40	$91.40
Year 2	1.2	$19.00	2.0	$37.00	108.0	$96.80	105.9	$89.64	$91.40
Year 3	1.1	$20.00	2.0	$39.00	113.8	$100.00	109.4	$87.88	$91.40
Year 4	1.0	$21.00	2.0	$41.00	119.6	$103.00	112.7	$86.13	$91.40
Year 5	1.0	$21.50	2.0	$46.00	131.2	$113.50	124.2	$86.49	$91.40
Annual Rate of Change (per cent)	-5.11	3.62	0.00	6.23	**5.59**	**4.43**		**-1.10**	**0.00**

When the deflation procedure is carried out, the output-price index deflator gives the correct result, real output has been constant over the five years, one truss is always the output (labour productivity has increased from $70.31 per hour to $91.40 per hour). In contrast, when the input-cost index is used to deflate nominal output, real output is estimated to have declined by 1.1 per cent per year, an estimate we know is incorrect (labour productivity has increased from $70.31 per hour to $86.49 per hour) (Chart 1).

Chart 1: Bias in Productivity Estimates Resulting from the Use of an Input-Cost-Index Based Deflator



Appendix III: The Impact of Prework on Construction Productivity Statistics

An example illustrates the technical reasons why a shift to prework, even more productive prework, will not necessarily increase productivity in the construction industry (Table 1). As has been noted previously in this study, productivity can be measured on a gross-output or value-added basis. The example involves a shift from building roofs using roof trusses built on site to using prefabricated roof trusses.

The top panel of Table 1 illustrates three different combinations of construction inputs and prework. The first combination involves no use of prework, that is, no prefabricated trusses. Trusses are built on site using 100 hours of labour. One hundred hours of labour are expended on other construction tasks, resulting in a total of 200 hours worked in the construction industry. Since there was no prework involved, total hours worked were also 200. These 200 hours of work resulted in 10 roofs being built. Therefore, the output of roofs per hour worked was 0.05 in the construction industry. Coincidently, the output per hour of roofs for all industries involved in roof building was also 0.05, since only the construction industry was involved in building roofs.

The second scenario involves the out-sourcing of roof truss fabrication to a manufacturing establishment. At the same time, there is no labour saving compared to the previous scenario in which the roof trusses were built on site. Roof trusses still take 100 hours to build, except they are no longer built in the construction industry, but in the manufacturing industry. As a result, the total hours worked required to build 10 roofs remains at 200, but these hours are now equally divided between the construction and manufacturing industries. What happens to productivity? The productivity of the construction industry, based on gross output, doubles from 0.05 roofs per hour to 0.1 roofs per hour. At the same time, there has been no overall gain in roof-building productivity, which is the same as in the previous scenario at 0.05 roofs per hour as total labour input is unchanged. This lack of overall productivity gains occurs because the total hours required to build a roof remain unchanged.

The third and final scenario in the top panel of Table 1 examines what happens to gross-output based productivity when prefabricating trusses in the manufacturing industry is more productive than building them on site in the construction industry. In this case let us assume that it only takes 60 hours to prefabricate trusses in the manufacturing industry rather than the 100 hours it took to build them on site in the construction industry. The other construction industry work associated with roof building remains stable at 100 hours. Therefore, the total hours required to build 10 roofs has been reduced to 160 hours from 200 hours. Now something quite interesting happens when we turn to the productivity numbers. In spite of the very great productivity improvement in manufacturing (100 hours down to 60 hours to do the same job), the productivity of the construction industry remains the same, at 0.1 roofs per hour worked. However, the productivity improvement shows up in the overall productivity of roof building, which has increased 25 per cent from 0.05 to 0.0625 (column H). We see from this example that productivity gains that occur in mod-shops and fab-shops or other prework facilities that are outside of the construction industry, are not captured in the construction industry productivity data.

Table 1: The Impact of Prework on Productivity in the Construction Industry: a Simulation

	Gross Output							
	Hours worked					Number of Roofs Built	Labour Productivity (roofs per hour worked)	
	Manufacturing	Construction		Construction Subtotal	Total		Construction Industry	Roof Building
	Trusses	Trusses	Other					
	A	B	C	D = B+C	E = A+B+C	F	G = F/D	H = G/E
No pre-work	0	100	100	200	200	10	0.05	0.05
Pre-work	100	0	100	100	200	10	0.1	0.05
More productive pre-work	60	0	100	100	160	10	0.1	0.0625

	Value Added							
	Value of Inputs					Value of Outputs	Value Added of Construction Industry	Value added per hour worked in the construction industry
	Manufacturing	Construction		Construction Subtotal	Total			
	Trusses	Trusses	Other					
	I	J	K	L = J+K	M = I+J+K	N	O = N-I	P = O/D
No pre-work	0	$1,000	$1,000	$2,000	$2,000	$2,000	$2,000	$10
Pre-work	$1,000	0	$1,000	$1,000	$2,000	$2,000	$1,000	$10
More productive pre-work	$600	0	$1,000	$1,000	$1,600	$1,600	$1,000	$10

The bottom panel of Table 1 illustrates the value-added approach to productivity measurement using the same three basic scenarios used in the top panel. In this case, inputs and outputs of the construction industry are valued in dollars. In the first scenario, “no prework”, 100 hours of labour at $10 per hour (= $1,000) are used building trusses in the construction industry, and 100 hours of labour at $10 per hour (=$1,000) are used for other roof-building tasks. The total value added in roof building is $2,000. For the sake of simplicity of analysis, let us assume that there are no profits in the construction industry, the value of output is $2,000.[25] Therefore, since all of the output was produced solely in the construction industry, with no inputs from any other industry used, the value added of the construction industry is the same as the value of output, that is, $2,000. When this value is divided by total hours worked to produce it, that is, 200 hours (column D in top panel), the output per hour worked is $10.

In the second case, that is trusses are fabricated in the manufacturing industry, but with no productivity gain, there will be no impact on labour productivity. The cost of the labour used to construct the trusses bought by the construction industry from the manufacturing industry is $1,000, the same cost that the construction industry would have incurred if it had constructed the trusses itself. The value added of the construction industry falls from $2,000 to $1,000 and the value added of the manufacturing industry rises from $0 to $1,000. Total value of output remains unchanged from the “no prework”

[25] The assumption of zero profits is common in economic analysis. In this case is does not detract from the explanation.

scenario at $2,000. Similarly, the value added per hour worked in the construction industry is also unchanged at $10. Labour productivity is unchanged because both the value added and the hours worked in the construction industry have fallen in the same proportion.

The final scenario in the bottom panel of Table 1 sees a productivity gain in trusses prefabrication in the manufacturing industry, that is the hours required to make trusses fall from 100 to 60. This reduction in hours results in a reduction in the cost of trusses that the construction industry buys. Other costs incurred by the construction industry associated with building roofs remain the same at $1,000. As a result value added of the construction industry is $1,000, and value added of the manufacturing industry is $600. The total value of output is $1,600, compared to $2,000 in the two previous scenarios. However, the crucial point of this example is that value added per hour worked still remains unchanged, at $10.

Perhaps the conception of productivity held by many construction practitioners more closely resembles gross-output productivity (Table 1, top panel, column H), which will rise with a shift to more productive prework. On the other hand, statisticians are more concerned with value-added based productivity (Table 1, bottom panel, column P), which will not rise with the shift to more productive prework.

Appendix IV: List of Appendix Tables
(posted at http://www.csls.ca/reports/csls2007-01-Tables.pdf)

Canada:

I: Value Added and Gross Output

II: Inputs

III: Productivity

IV: Price Index

United States

I: Value Added and Gross Output

II: Inputs

III: Productivity

International