Productivity in the Construction Industry:

Concepts, Trends, and Measurement Issues

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Goals

Overall Goal:

Constructed products that are less costly to build and which perform better in terms of durability and maintenance over their life. This goal can be advanced by greater efficiency in the construction process, better architectural and engineering design, and the use of superior performing components supplied by manufacturers.

Objective of this project:

To review the salient themes in the economic and engineering literature so as to provide a framework for subsequent research that will support IRAP's work with the Construction industry.

Outline of Presentation

1. A primer on productivity
2. Statistical measures of the construction industry
3. Productivity trends in the construction industry
4. Measurement issues
5. Conclusions and implications for further research

Part I

A Primer on Productivity

A Primer on Productivity: Definition of Productivity

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

Productivity is the ratio of output to all or some of the resources used to produce that output.

Output can be homogenous or heterogeneous.

Resources comprise: labour, capital, energy, raw materials, etc.

The productivity ratio can relate output to all resources used ('Multi-Factor Productivity' or 'Total Factor Productivity') or to a single factor, such as units of labour or capital or energy. The most common single factor productivity measure is labour productivity.

A Primer on Productivity: Measuring Output

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

If output is homogenous (*e.g.*, amount of concrete poured), it can be measured in physical units (*e.g.*, cubic metres).

If output is heterogeneous, it must be measured in value terms.

If a time series is desired, the effect of inflation must be taken out of the value measurement, through the use of a price index (or 'deflator'). Deflated values are referred to as 'real values'.

Deflators can be in 'constant dollars' or 'chained dollar'. A 'chained dollar' index takes account of substitutions that occur when the prices of input change at different rates. 'Chained dollar' deflators are only available back to 1997.

If the quality of the output changes over time, an allowance must be made for the improvement or reduction in quality.

A Primer on Productivity: Measuring Output (continued)

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

In the case of construction, these output measurement issues are especially difficult and complex owing to the extreme heterogeneity of constructed products.

The US Dept of Labor does not publish labour productivity data for the construction industry because it has low confidence in the reliability of the price indices used to estimate real output.

Statistics Canada, however, does publish labour productivity for construction.

A Primer on Productivity: Measuring Input (Resources Used)

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

The three most commonly used productivity ratios, based on 'resources used' are:

- Total Factor Productivity* – output in relation to all resources used
- Labour Productivity – output in relation only to labour used
- Capital Productivity – output in relation only to capital used

* also termed 'Multi-Factor Productivity'

A Primer on Productivity: Measuring Labour Input

$$\text{Productivity} = \frac{\text{Output}}{\text{Labour Input}}$$

Labour can be measured as:

- persons employed (the most available)
- hours worked (the most accurate)
- labour cost

Account also needs to be taken of changes in the quality of labour. Educational attainment is the usual proxy for quality. In construction, this proxy is less reliable, since many skills are acquired through the trade system and through experience.

A Primer on Productivity: Measuring Capital Input

$$\text{Productivity} = \frac{\text{Output}}{\text{Capital Input}}$$

'Capital' refers to physical capital, not investment. Physical capital is machinery and equipment.

Physical capital is measured at a depreciated value, which is only an approximation of wear and tear.

The 'capital input' is the service provided by a piece of capital in the production of output. The service is the amount of the capital that is consumed in production as a result of wear and tear.

Obsolescence is a complicating factor. High rates of technological innovation can result in a more rapid write off rate (depreciation) than is used in the economic estimates. In other words, the economic estimates can underestimate the capital input.

A Primer on Productivity: Defining Construction

$$\text{Productivity} = \frac{\text{Construction Output}}{\text{Resources Used}}$$

The construction industry (as an economic definition) comprises both:

- the 'contract construction industry', *i.e.*, the industry composed of companies that undertake construction for an owner, and
- 'own-account' construction which is undertaken by non-construction organizations for their own purpose.

'Own account' construction is 10-15% of total construction. 'Own account' construction is undertaken mainly by mines, the forest industry, and governments. 'Own account' constructors may be slower to adopt productivity-enhancing methods.

Some economic measures of construction include repair, others refer only to 'put in place' construction (i.e., new construction).

The estimate of 'repair construction' is exceedingly problematic since many asset owners maintain their own maintenance work force.

A Primer on Productivity: Construction vs. Manufacturing Work

$$\text{Productivity} = \frac{\text{Construction Output}}{\text{Resources Used}}$$

Construction is on-site work. Work that is done in a plant is considered manufacturing work, not construction work. For example, pre-cast concrete is a manufactured product. Installing pre-cast is construction work.

This is an exceedingly important distinction. Much of the technological progress in constructed products consists of increasing the amount of work that is done in a plant setting and transporting those components to a construction site for installation or erection. In this situation, the contribution to higher productivity may be allocated to the manufacturing employer, rather than the construction employer. In other words, declining or stagnant labour productivity in the construction industry could be associated with overall gains in the efficiency with which constructed products are built, but those gains could show up as improvements in productivity in the manufacturing sector.

A Primer on Productivity: Diversity of the Construction Industry

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

Construction is a diverse and complex industry. Construction companies can be distinguished by:

- **the trade work they do,**
- **the sectors they work in,**
- **the size of projects they undertake,**
- **whether they are union or non-union***
- **the size of their work force.**

It can be misleading to reduce such a diverse and complex industry to a single measure of labour productivity.

***The typical union crew is smaller and comprises journeypersons and apprentices, with a few helpers. The typical non-union crew is larger, and comprises more helpers, semi-skilled workers and fewer journey-persons and apprentices.**

A Primer on Productivity: Productivity vs. Competitiveness

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

Productivity is not the same as competitiveness, though it is an important dimension of competitiveness.

Competitive advantage can be founded on:

- **the price of the resources used (*i.e.*, labour, capital, energy, etc.),**
- **distinctive technologies that affect productivity,**
- **reputational factors for quality and reliability.**

Unit labour cost links labour productivity to the price of labour.

$$\text{Unit Labour Cost} = \frac{\text{Hourly Compensation}}{\text{Labour Productivity}}$$

A Primer on Productivity: Productivity vs. Competitiveness (continued)

$$\text{Unit Labour Cost} = \frac{\text{Hourly Compensation}}{\text{Labour Productivity}}$$

If the growth of hourly compensation exceeds the growth of labour productivity, unit labour costs increase.

Conversely, if labour productivity growth exceeds the growth of hourly compensation, unit labour costs decrease.

A change in unit labour costs may be reflected in a change in output prices or a change in profit margins.

A Primer on Productivity: Capital Productivity

$$\text{Capital Productivity} = \frac{\text{Output}}{\text{Capital Input}}$$

While attention is usually focused on labour productivity, the importance of capital productivity should also be borne in mind.

Estimates of capital productivity for the construction industry as a whole suggest that it declined in the late 1980s and remained stagnant thereafter. A deterioration in capital productivity necessarily reduces output per unit of labour.

$$\text{Capital Productivity} = \frac{\text{Output}}{\text{Capital Services}}$$

Capital services is an estimate of the production services derived from fixed assets. The measurement of the capital stock and the production services from the capital stock is subject to estimation error that could be significant.

A Primer on Productivity: Productivity in Perspective

$$\text{Productivity} = \frac{\text{Output}}{\text{Resources Used}}$$

Productivity growth is the foundation of improved living standards.

Productivity is also important to competitiveness, though it is not the sole determinant of competitiveness.

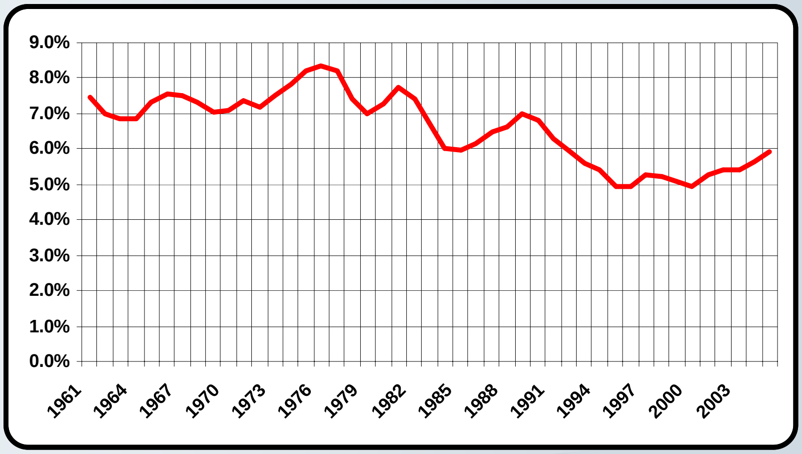
The buyers of construction products differ in the relative importance that they attach to cost and to the uniqueness of design and finish.

There are powerful forces that originate on the demand side which inhibit productivity growth because of a strong preference on the part of some buyers of constructed products for uniqueness of location, design and finish.

Part II

Statistical Measures of the Construction Industry

Construction as a Share of GDP (current dollars), 1961-2005



Statistics Canada, CANSIM 379-0023 and 379- 0024

Recently construction has accounted for <u>6.0% of GDP</u>.

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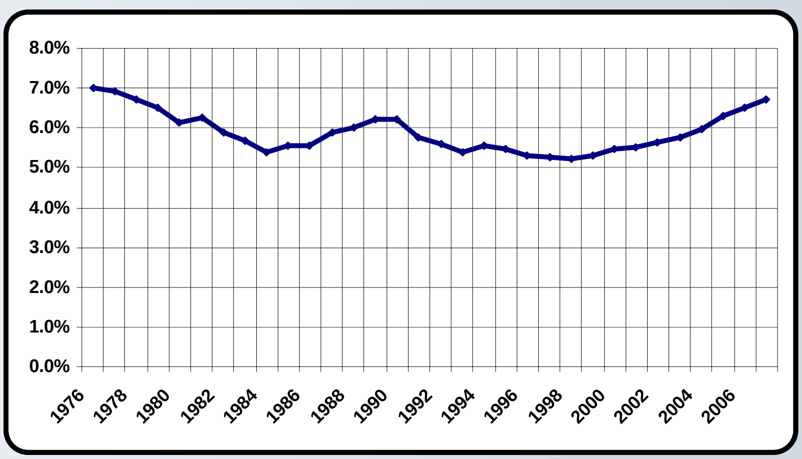
Construction Share of Total Employment (LFS basis), 1976-2007



Statistics Canada, Labour Force Historical Review, 2007

Recently construction has accounted for <u>6.7% of total employment</u>.

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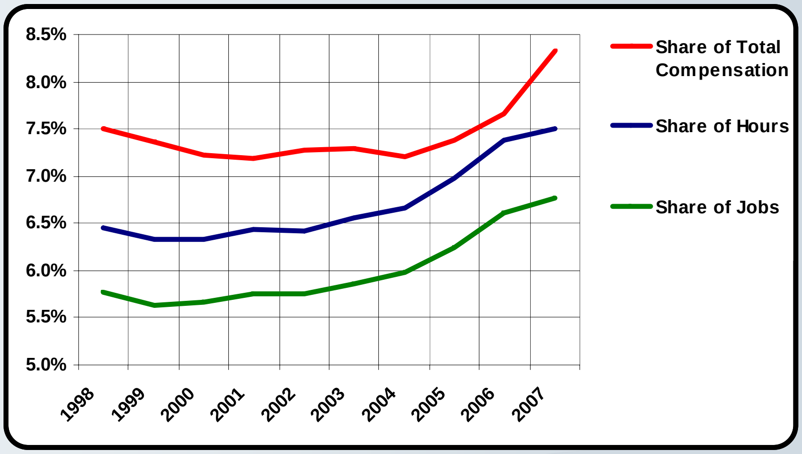
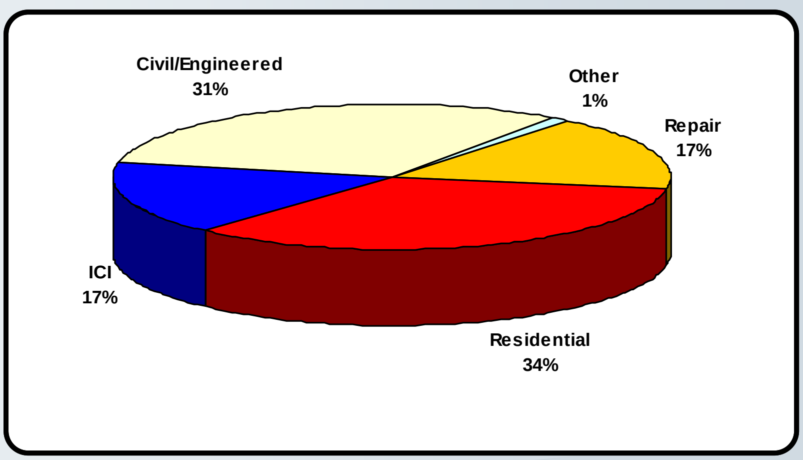
Construction Share of Employment – Other Measures, 1998-2007



Statistics Canada, CANSIM383-0009

Other measures suggest higher estimates of construction's share in Employment: 7.5% of total hours, 8.3% of total compensation.

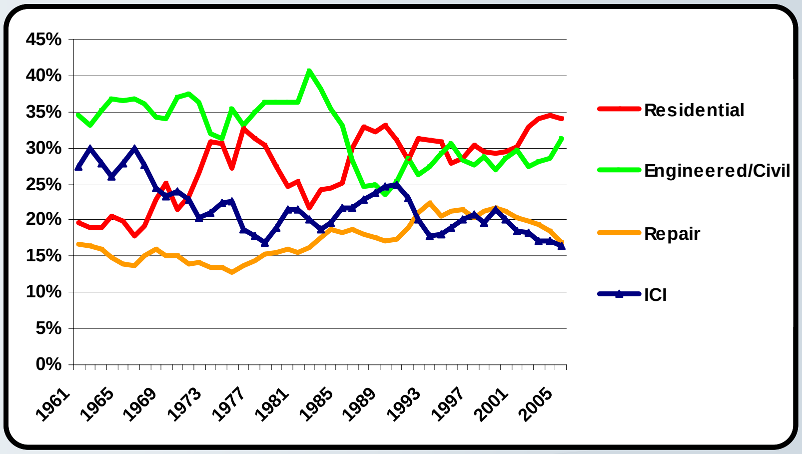
Share of Construction Sub-Sectors, 2005



Statistics Canada, CANSIM 379-0023

Sector shares are important because they can have quite different productivity trends. Civil construction is the most amenable to mechanization. Repair is the least amenable.

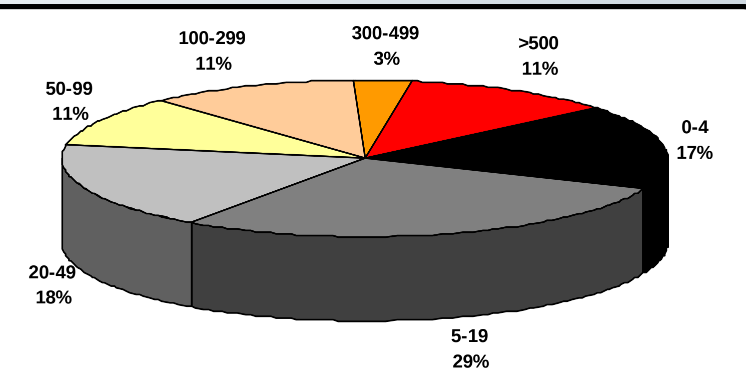
Change in Shares of Construction Sub-Sectors, 1961-2005



Statistics Canada, CANSIM 379-0023

There is considerable volatility in sectoral shares.

Construction Employment by Size of Employer

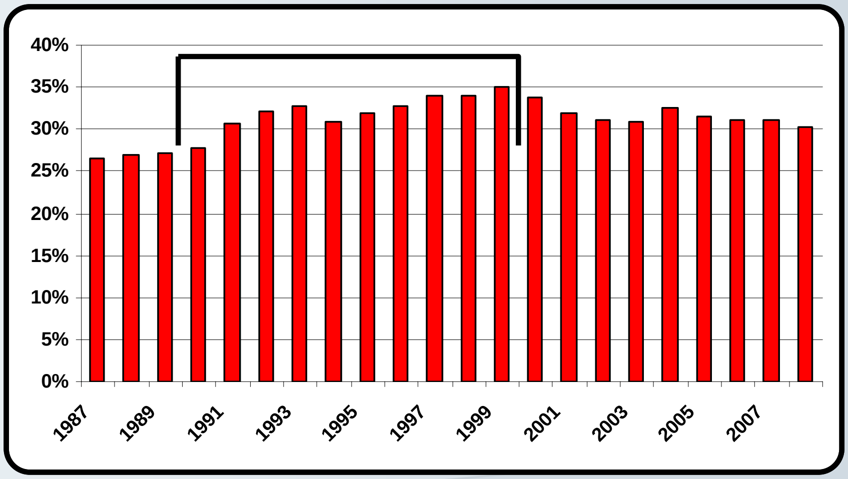


Firms with fewer than 20 employees, account for 46% of construction employment.

Statistics Canada, CANSIM 281-0041

Construction is <u>dominated by small employers</u>. Small employers tend to be more conservative in regard to innovation.

Share of Self-Employment in Construction



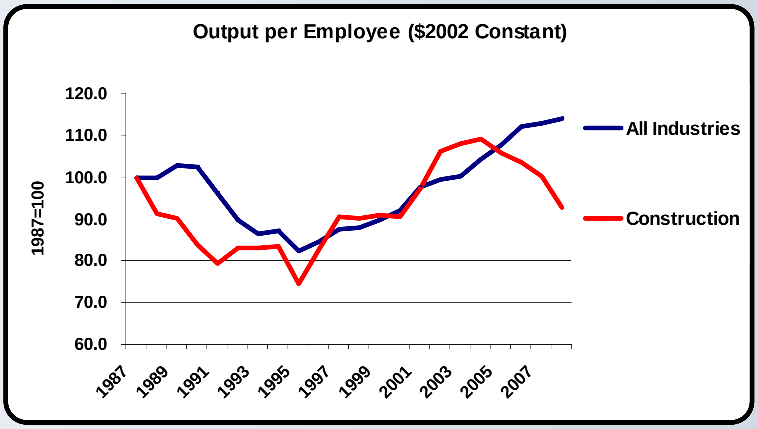
Statistics Canada, CANSIM 282-0012

Self-employment accounts for 30% of construction employment. The self-employment share increases during downturns. High rates of self-employment are inimical to mechanization.

Part III

Productivity Trends in the Construction Industry

Labour Productivity: Productivity Trends 1987-2008



Statistics Canada,, CANSIM 397-0027, 282-0011
Indexed to 1987=100

From 1987 to 2004, labour productivity in construction tracked overall trends in the economy. In the past four years, the boom in construction appears to have reduced labour productivity. Weak productivity growth in the economy as a whole was mirrored in the construction industry.

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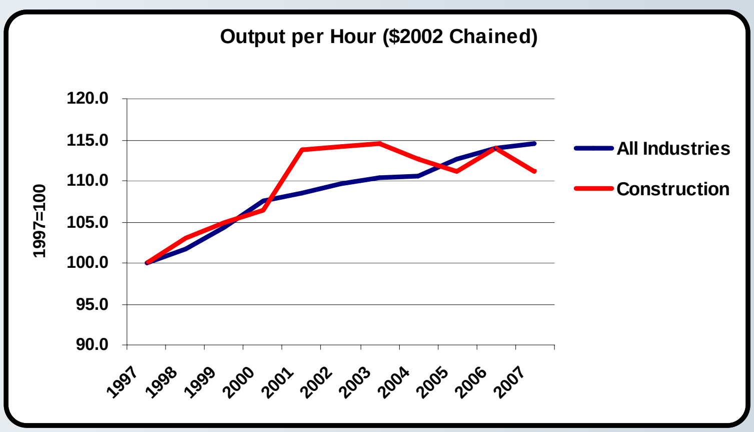
Labour Productivity: Productivity Trends 1997-2007



Statistics Canada,, CANSIM 397-0027, 383-0012
Indexed to 1989=100

<u>The picture changes somewhat when we measure output using a 'chained dollar deflator' and labour input in hours, rather than employment</u>.

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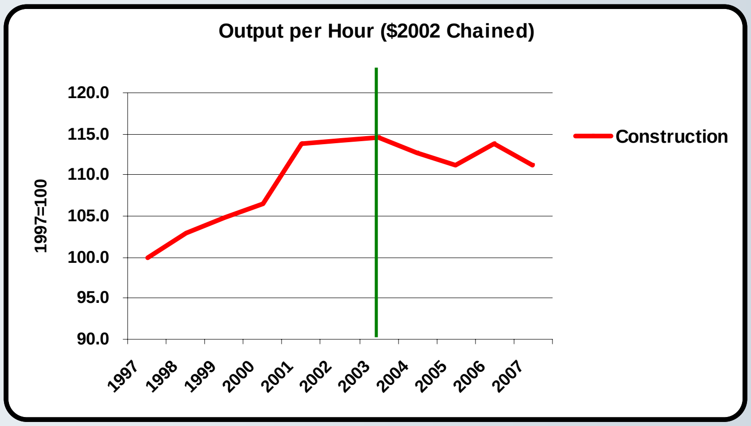
Labour Productivity: Construction 1997-2007 - A Closer Look



Statistics Canada,, CANSIM 397-0027, 383-0012
Indexed to 1989=100

1997-2001: rising productivity (slack labour conditions)

2001-2003: stagnant productivity as labour markets tightened

2004-2007: falling productivity as less skilled labour is hired, equipment and materials shortages emerge, and management resources are 'stretched'

Labour Productivity: Estimated Productivity Trends Compared

	All Industries	Construction
Average Annual Growth – Labour = Employment – Deflator = $2002 Constant – Period: 1987-2008	0.62%	Nil (to 2007) -0.04% (to 2008)
Average Annual Growth – Labour = Hours – Deflator = $2002 Constant – Period 1997-2007	1.42%	0.97%
Average Annual Growth – Labour = Hours – Deflator = $2002 Chained – Period 1997-2007	1.37%	1.07%

Labour Productivity: Different Measures = Different Implications

- Different measurement procedures support radically different conclusions.
- The impact of measurement problems becomes more significant, the longer the time series.

Thus:

- Using 1987-2008 as the measurement period, using employment as the measure of labour input, and using a 'constant dollar' deflator suggests zero or negative productivity growth in construction, i.e., a systemic productivity problem.
- Using 1997-2007 as the measurement period, using hours as the measure of labour input, and using a 'chained dollar' deflator suggests a moderate productivity lag (largely the result of 2007 data), but does not support claims of a systemic productivity problem in the construction industry.

Part IV

Measurement Issues

Measuring Output: The Deflator Problem

- There are two ways of constructing output price indices for construction products:

  (1) Surveying <u>output</u> prices in relation to a fixed physical unit, e.g., cost of producing a mile of asphalt highway

  (2) Survey <u>input</u> prices and then summing these to estimate the likely output price.

- In construction, it is exceedingly difficult to monitor output prices. Consequently, <u>construction price indices are predominantly constructed using input prices</u>.

- However, reliance on input-based price deflators can under-estimate output and thereby under-estimate productivity growth. This measurement error increases, the longer the time series used. (Dacy and Gordon)

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Critique of Input-based Price Indices: Dacy and Gordon

(Douglas C. Dacy, *Review of Economics and Statistics*,1965)
(Robert J. Gordon, *Review of Economics and Statistics*,1968)

1. Owing to the heterogeneity of construction products, construction price indices are based on input prices not output prices.
2. Because of rising productivity (and sometimes falling profit margins), <u>input prices for labour rise faster than output prices</u>. This happens in many sectors of the economy and is the reason that living standards rise, *i.e.*, wages normally rise faster than prices.
3. However, if an index based on input prices is used to deflate nominal output values, the result will be to over-deflate nominal output, *i.e.*, real output will be *under*-estimated.
4. <u>When output price indices are used in place of input price indices, the estimate of 'real output', and hence labour productivity, in US construction increased by 40% between 1948 and 1965</u>.

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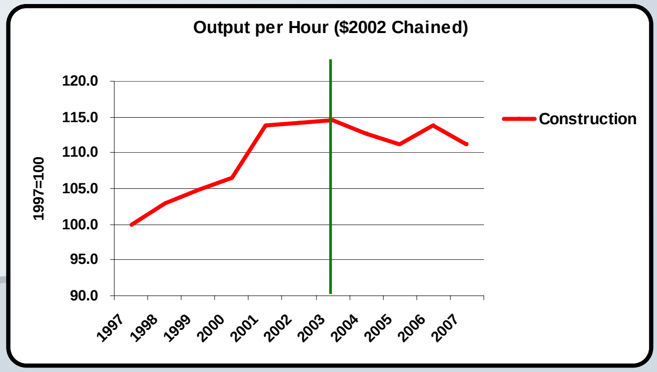
Measuring Productivity: Timing affects the trend estimate

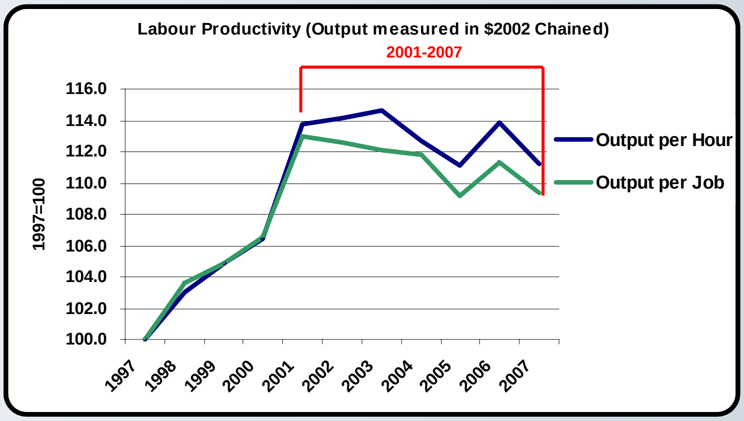
- **By any measuring procedure, productivity in construction is more cyclical than productivity in the manufacturing sector or on an economy-wide basis.**
- **Consequently, estimates of long-run productivity are strongly influenced by the selection of the start and end years for the time series.**



Measuring Productivity: Labour Input – Hours vs Employment

- **Hours differ significantly across branches of construction.**
  - **ICI is 40 hours per week for most trades, by 36 hours for unionized electrical and mechanical trades in many provinces. This is sometimes worked as 4x9 and sometimes as 5x8 with overtime paid on the last 4 hours.**
  - **In civil construction (roads, etc.) 10 hours/day is the norm, including Saturday work.**
  - **In low-rise residential construction, piece-rate payment predominates. Hours typically exceed 40 per week.**
  - **25-35% of the construction labour force is 'self-employed'. Estimates of average weekly hours are problematic for this group.**
- **In construction, unlike other sectors, there can be significant divergences in the productivity measure between hours-based and employment-based measures of labour input.**

Measuring Productivity: Labour Input – Hours vs Employment



Statistics Canada,, CANSIM 397-0027, 383-0009
Indexed to 1997=100

Using employment, productivity fell from 2001 to 2007 by 3.3%.

Using hours, productivity fell from 2001 to 2007 by 2.3%

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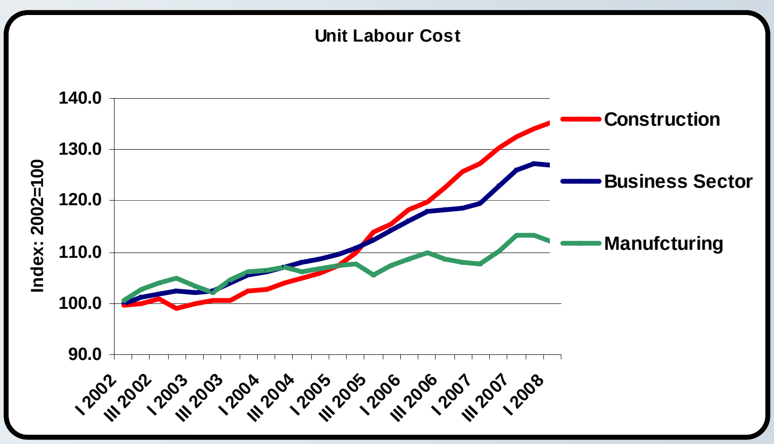
Changes in Unit Labour Cost, 2002-2007



Statistics Canada CANSIM 383-0012

After 2005, the boom in construction markets drove up labour costs (as well as materials inputs). The more intense competitive pressures arising from the higher dollar depressed labour cost increases in manufacturing, but not in services.

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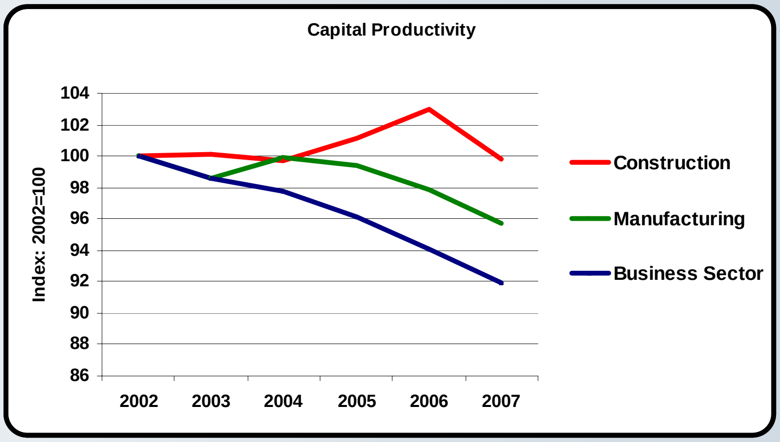
Capital Productivity



Statistics Canada CANSIM 383-0021

Data suggest a general decline in the productivity of capital, though less marked in construction. Capital productivity is affected by cyclical factors, especially declining capacity utilization rates which increase the amount of fixed capital consumed in producing lower outputs.

Importance of Pre-Fabricated Components

Charles Eastman and Rafael Sacks
Journal of Construction Engineering and Management (2008)

- **The authors estimate growth in value-added per employee from 1992 to 2002 for manufacture of construction components and for construction activities that are predominantly on-site activities. Substantially higher productivity growth in manufactured components.**

	Average Annual Increase in Value-Added per Employee
Off-Site Manufacturing of Components – Metal window & door manufacture – Curtain wall fabrication – Structural steel fabrication – Pre-cast concrete fabrication – Elevator manufacture	2.32%
On-Site Construction Activities – Curtain wall erection (glazier contracting) – Structural steel erection – Drywall and insulation – Cast-in-place concrete	1.43%

Activity-Based Measures of Productivity

- Activity-based measures of productivity focus on particular construction activities, using the Construction Specification Institute's definition of construction activities.
- Productivity is measured as activity-output in either physical or value terms, depending on the nature of the activity.
- Input is measured in labour hours.
- Data is based either on:
  - actual site surveys, or
  - benchmarks used in costing manuals, such as
    - R.S. Means, *Building Construction Cost Data*
    - Richardson*, Process Plan Construction Estimating Schedules*
    - *F.W. Dodge, Dodge Cost Guides*
    - In Canada would use: *Hanscomb's Yardsticks for Costing*
- Activity-based measures of productivity are significantly higher than economic estimates for the US construction and marginally-to-moderately higher than economic estimates for the Canadian construction industry.

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Activity-based Measurement of Productivity

Eric Allmon, Carl Haas, *et al*., *Journal of Construction Engineering and Management*, 2000

Paul Goodrum, Carl Hass, *et al, Construction Management and Economics*, 2002

1. Examine 200 common construction activities using Means, Richardson and Dodge estimating manuals over a 22 year period, holding location constant.
2. Deflate these costs using the Consumer Price Index.

Estimates of labour productivity, 1976 to 1998		
	No. of Activities	Average Annual Labour Productivity
Means Building Construction Cost Data	100	+0.8%
Richardson Process Plant Construction Estimating Schedules	50	+1.2%
Dodge Cost Guide	50	+1.8%

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International Comparisons

TABLE 1 —PRODUCTIVITY GROWTH RATES BY INDUSTRY AND COUNTRY 1970–1987

Average Growth Rates of Total Factor Productivity

Country	Agriculture	Mining	Manufacturing	Utilities	Construction	Service	Total Industry
U.S	015	–.037	016	.006	–.020	002	003
Canada	009	–.060	008	006	.014	.006	004
Japan	– 002	.018	040	– 012	–.022	.005	015
W Germany	043	–.028	015	003	.007	.005	013
France	040	– 036	017	.027	009	012	.017
Italy	020	na	.029	–.017	–.017	na	010
U.K.	036	–.015	012	007	– 006	.005	.009
Australia	.018	–.008	014	019	008	na	.005
Netherlands	.044	.013	024	– 012	– 010	na	.013
Belgium	.037	– 012	.035	028	011	.005	.016
Denmark	.041	.082	.019	032	– 011	010	014
Norway	021	074	003	.004	–.003	.007	015
Sweden	020	– 037	011	.022	021	.009	.012
Finland	022	019	026	014	.015	.013	.017
Average	.026	– 002	.019	.009	– 000	.007	.012

Notes Average growth rates are calculated by regressing log productivity levels on a constant and a time trend Source data are from the OECD Intersectoral Database

Andrew Bernard and Charles Jones, *Review of Economics and Statistics*, 1996

International Comparisons

International comparisons construction productivity growth are problematic for three reasons:

1. **Construction productivity is subject to strong cyclical effects. Cycles are not consistent across countries.**
2. **Over long periods of time, how price deflators are constructed strongly influences estimates of real construction output and hence, estimates of productivity. There can be no presumption that price deflators are constructed in the same manner.**
3. **There may be differences in how the construction industry is defined, specifically in regard to the treatment of repair work and 'own account' work. These can account for 20-25% of the total.**

That being said, the Bernard and Jones study suggests:

- **During the period studied (1970-1987) <u>Canada did not lag</u> in construction productivity compared to other countries,**
- **Canada did have a systemic weakness in productivity growth across the economy as a whole, during this period.**

Assertions of a Systemic Productivity Problem in Construction

- There is both a US and a Canadian literature which argues that there is a systemic productivity problem in the construction industry. Construction is said to lag behind the business sector as a whole and the manufacturing sector, in particular.
- The cause of this 'systemic problem' is variously attributed to:

  (1) A decline in the ratio of skilled-to-unskilled labour attendant upon an increase in the non-union share of construction,

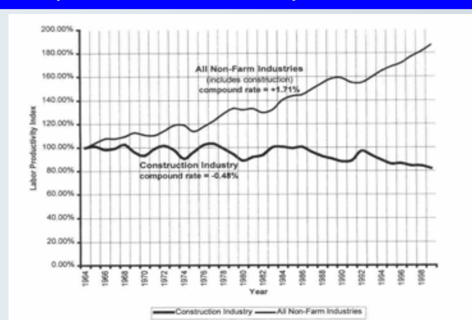
  (2) Stagnation in labour quality compared to improved labour quality in the economy as a whole, where 'labour quality' is proxied by educational attainment,

  (3) Lower capital/labour ratios arising from the craft nature of many construction processes,

  (4) Lower absorption of IT which has been a productivity driver in other sectors,

  (5) Increased use of pre-fabricated components which capture the productivity gains in the manufacturing sector, not in construction.

Assertion of a Systemic Productivity Problem in Construction: US



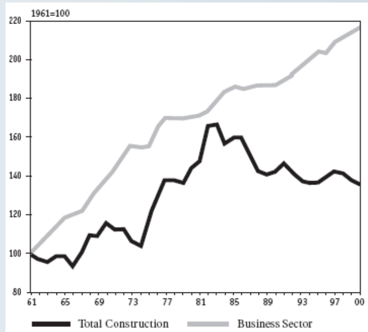
P. Teicholz, *Journal of Construction Engineering and Management* (2001)

"[Using Bureau of Labor Statistics data], the index for the construction industry shows a steady decline at a compound rate of -0.48% per year… over the 1964-1999 time period."

Rojas and Aramvareekul, *Journal of Construction Engineering and Management* (2003)

"[Using Bureau of Labor Statistics data], it cannot be determined if labor productivity has actually increased, decreased or remained constant in the construction industry for the 1979-1998 period"

Assertion of a Systemic Productivity Problem in Construction: Canada



Source: Aggregate Productivity Measures, May 2001, Statistics Canada.

A. Sharpe, *International Productivity Monitor* (2001)

"Over the 39 year period [1961-2000], the construction sector experienced less than one half the average annual rate of increase in output per hour of the business sector - +0.8 per cent versus +2.0 per cent."

"Despite an increased capital-labour ratio and higher levels of educational attainment in the workforce, labour productivity in the construction sector in Canada was lower in absolute terms at the end of the 1990s than in the early 1980s."

Assertion of a Systemic Productivity Problem in Construction: Canada

Peter Harrison, *Can Measurement Error Explain the Weakness of Productivity Growth in the Canadian Construction Industry* (2007)

- **Labour Productivity, 1981-2006:**
  - **Business Sector: +1.46% per year**
  - **Construction: +0.53% per year**
  - **Gap: +0.93% per year**
- **Measurement error, chiefly arising from reliance on input-based deflator indices, accounts for at most one half (0.44%) of the gap in productivity.**
- **There is no evidence that the use of pre-fabricated components is increasing. In any event, there is no a priori reason for this increase to reduce productivity in the construction sector.**
- **Note that Harrison's estimate of +0.97% per year is similar to the activity-based estimates in the US which average 1.15% per year**

Comment on 'Systemic Productivity Problem':

- The most recent data (Slide 37) do not support such a strong conclusion, when cyclical factors are taken into account.
- Assertions of a systemic productivity problem are at odds with activity-based estimates of productivity growth, and also at odds with industry perceptions.
- Proponents of the 'systemic problem' view under-estimate the significance of measurement issues and the importance of pre-fabricated components.
- In any event, the diversity of the construction industry militates against sector-wide advances in productivity. A focus on sub-sectors and on trades is more appropriate.

Part V

Conclusions and Implications for Further Research

Conclusions and Observations:

1. The <u>measurement issues are serious</u> and preclude relying on long-term time series data to draw strong conclusions about systemic trends.

2. The measurement issues, especially those related to timing, also preclude relying on cross-national data series to compare productivity trends, even when methodology is otherwise commensurate (which it rarely is).

3. The most current Statistics Canada data series (Slide 27: output per hour for 1997-2007, using a chained dollars deflator) is a reasonable depiction of recent trends that also coincides with industry perceptions, especially in relation to cyclical influences.

4. <u>Use of pre-fabricated components is important and is increasing</u>.

5. <u>Activity-based measures are more reliable and more relevant</u> to industry. Reliance on costing manuals, however, is problematic.

Implications for Further Research

Opportunities to improve the cost and quality of built products fall into four categories:

1. Improvements in <u>trade processes</u> through the adoption of new machinery and equipment, new materials, or new methods.

2. Improvements in the <u>management and co-ordination</u> of trade processes to eliminate non-productive time and re-work.

3. Improvements in <u>pre-fabricated components</u> such that total cost is reduced and/or performance of the constructed product is improved.

4. Improvements in <u>architectural and engineering design</u> that maximize the opportunity to exploit improvements in trade processes, management and co-ordination, and the use of pre-fabricated components.

Subsequent research should identify innovations in these four categories and explore the factors that promote or inhibit their adoption, and in particular the potential role of technology advisors in overcoming constraints on adoption.