Catalogue no. 62F0014MIB

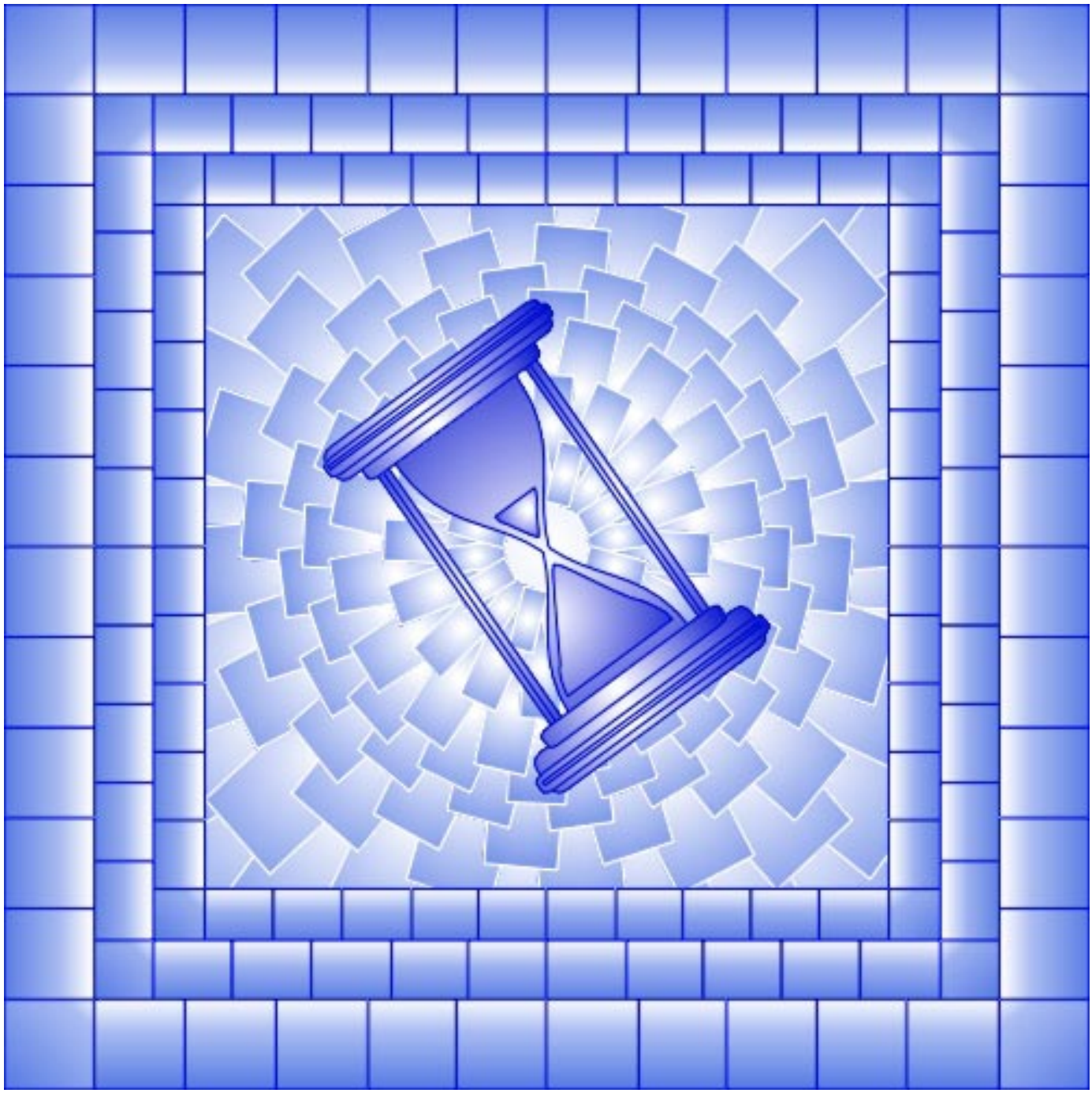
Analytical Series

Prices Division

Productivity Adjustment in Construction Prices Indexes

By Rasool Mohammadian and Lloyd Waugh

No 3



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Productivity Adjustment in Construction Price Indexes

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Catalogue No. 62F0014MPB, No. 3
ISBN: 0-660-59262-2
ISSN: 1206-2677

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April 1997

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Texte français au verso

Abstract

Productivity analysis is one of the major foundations of the analysis of long-term economic growth. It is important to study productivity in order to identify the factors that contribute to it and to explore the relationship that exists between productivity, growth and international competitiveness.

Statistics Canada produces partial productivity indexes for some 30 industries and the business sector of the economy on an annual basis. However, little is known about the real output, productivity, and price trends in the construction industry. Four opportunities for productivity research in the construction industry are evident, (a) investigation of the available productivity measures, (b) alternative approaches to the implicit methods currently used in the compilation of output price indexes, (c) estimation of productivity within particular sectors of the construction industry, and (d) comparison of productivity on an interprovincial or international basis.

In this paper we will focus on the first two of the four alternatives and will give examples of the last two. In particular, by formalizing the adjustments that are made to the input factors used in the development of output indexes, we contend that the result will be more impartial and enduring. Generally, our goal is to investigate and promote measures that will be available and attractive to the construction industry as it begins to demand more electronic information. The purpose is to derive, eventually, some new productivity estimates based upon the best available statistics.

Cover design concept by Paul-Roméo Danis, Prices Division

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1. Introduction

Productivity measures are used as tools for analysing the effects of technological changes on economic growth, output, employment, the development of appropriate policies to combat inflation and to strengthen international competitiveness. An appropriate construction productivity measurement will help owners and construction managers determine the effects of changed methods or conditions on the economics of a construction project such as trade-offs of equipment versus labour and construction methodology.

Conceptually, productivity is defined as the ratio between the volume of outputs and the volume of inputs used to produce the output. In practice, measuring changes in construction productivity is not so simple because of the unique character of the construction industry. Output is a particular problem in measuring construction productivity because most construction products are diversified and unique, and hardly any two of them are alike. Total input is equally difficult to measure and many inputs must be combined to produce an output. In addition, there are various factors that bring about changes in productivity. It is difficult to group them into clearcut categories due to a strong interaction between these factors. Innovation, technological change and increased capital investment are among the most important factors that increase productivity. On the other hand, better managerial practices, improved working conditions and better utilization of known techniques and of the capacity of existing equipment can obviously enhance construction productivity. Accordingly, a single measure of the overall industry productivity, even if accurate, is insufficient for such a diversified industry as construction.

Statistics Canada currently develops construction productivity indexes at an aggregate level. However, there are no data available which can be used to compare rates of productivity gains in various sectors of the construction industry. While the aggregate productivity presents an overall perspective of productivity movements, the sub-industry studies could provide a fairly refined level of industrial detail. The studies allow us to compare various segments of the construction industry and to quantify some of the underlying relationships.

The objectives of this study are (a) to review the available construction productivity measurements, and (b) to investigate alternative approaches to the implicit methods currently used in the compilation of output price indexes for some sectors of the construction industry. Some measures of productivity in construction at industry segment levels are also examined.

2. Available Measures of Construction Productivity

A variety of productivity measures are compiled on a regular basis: Hanscomb (1995), ENR (1995), Means (1995), and many others. These measures provide very useful information for a specific audience, however, they are typically based on input costs rather than output prices, are limited to specific building types, and are not reviewed by an external agency. For these reasons, we will be focusing on methods of enhancing the productivity measures that are currently produced by Statistics Canada.

Two types of productivity measures are currently produced for the construction industry at Statistics Canada on an annual basis: labour productivity, and total-factor or multifactor productivity (See Catalogue No. 15-204). Labour productivity measures output per hour in the industry whereas the total-factor productivity includes not only labour input but also the services of plant and equipment (capital), sometimes energy, and materials. The calculation of total-factor productivity measurement is less difficult now than it was several years ago, before the introduction of new measurement techniques and recent developments in the theory of production (CED, 1983). Labour productivity is measured in terms of real GDP per person or real GDP per person-hour, both of which are based on a ratio of output to labour input, and are produced and presented in index number form.

Each type of measure has its advantages and its limitations. In each case, the output measure includes the effects of technological changes, the improved quality of capital goods, the increasing skill and education of the labour force, and many other sources of productive efficiency not purchased directly. Although labour input is an important determinant in the level of output, labour productivity is considered to be a partial productivity measure and ideally, a productivity index should take into account all input resources that are used in the production process. Consideration must also be given to: the time value of capital; the economics of bringing a facility in earlier by accelerating the schedule; the costs attendant to a suggested improvement in productivity such as heating; and value engineering concepts (Revay & Associates, 1981). Labour productivity measure is a partial productivity measure in that only labour is used as input, while capital, the other input determining value added, is ignored. The exclusion of capital could lead to misinterpretations, because an increase in the productivity of labour could, in fact, be due to the availability of more capital.

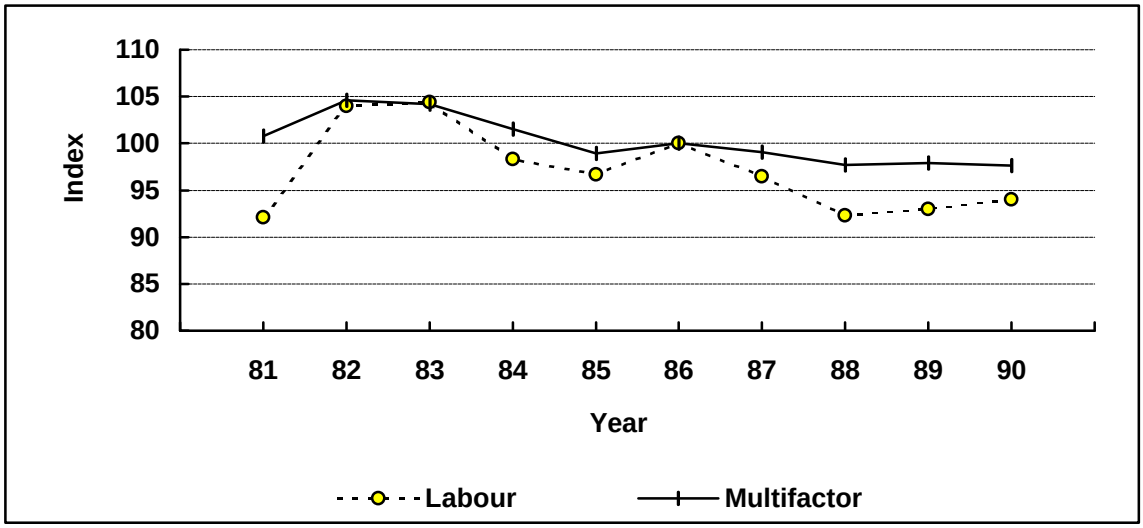
The use of a labour productivity measure is important for the construction industry, because of the unique character of the industry and because labour constitutes such a large part of the cost of construction. Labour represents, on average, 30 to 40% of the total construction costs (see Table 1). Moreover, the quantity of labour required is more susceptible to the influence of construction management than are quantities of either capital or materials.

Table 1. Input Cost, Input Productivity, and Output Price Indexes for Non-residential Construction, 1986=100

Year	Labour Index	Material Index	Labour Share	Input Index	Input Productivity Index	Output Index
1981	75.5	79.4	36.3	77.5	81.9	89.8
1982	82.6	84.4	36.6	83.6	87.8	96.8
1983	92.6	88.0	35.6	90.2	89.2	95.5
1984	95.6	91.4	34.6	93.4	90.3	93.7
1985	97.6	94.8	34.9	96.1	94.3	95.9
1986	100.0	100.0	35.1	100.0	100.0	100.0
1987	103.1	103.8	36.6	103.5	108.0	107.4
1988	107.6	110.5	37.9	109.1	119.1	114.8
1989	113.1	113.9	38.8	113.5	125.9	122.5
1990	116.4	113.4	39.2	114.8	126.8	126.0
1991	122.8	101.1	39.8	111.4	115.0	121.3
Average Annual Increase: (%)				3.73	3.59	3.13

The variation of multifactor and labour productivity indexes for the construction industry is shown in Chart 1, for the period 1981 to 1990. The labour productivity and related data derive from input-output tables, real gross domestic product by industry, and various surveys and censuses containing information on employment, hours worked, and labour income. Chart 1 demonstrates that labour productivity in the construction industry has declined during the past decade. While the general trend for productivity growth has been downward, the extent of this drop appears to be greater for labour productivity. The drop at the aggregate industry level appears to be about 10% (from 1982 to 1990). The causes of this productivity decline are debatable, but are probably the result of a combination of factors including the reduction in the capital and labour input as a result of falling output growth. When output declines, productivity temporarily falls back.

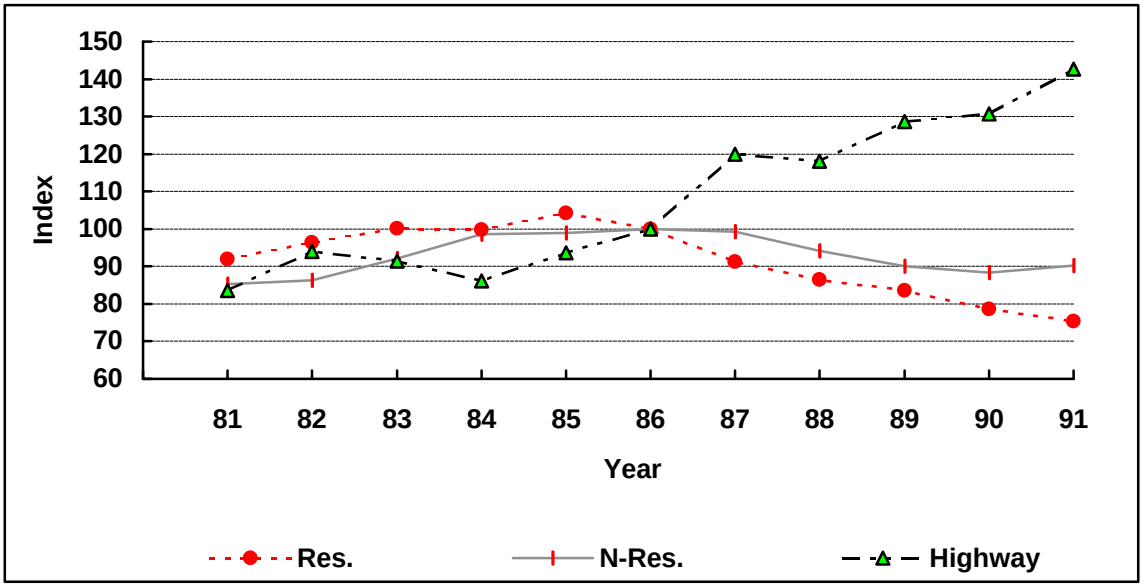
Chart 1. Labour and Multifactor Productivity Indexes for Construction Industry in Canada (GDP/Hour), 1986=100



3. Productivity Measures at Segmental and Regional Level

At present, there are no data available on productivity levels in the various segments of the construction industry. Major segments of the industry should, however, be examined separately and productivity measures should be devised for each. There should be measures that could be applied to particular segments of the industry, such as residential construction, highways, and power generation plants. In addition, some productivity measures should be narrow enough so that they are concerned with particular localities, metropolitan areas, or regions. This will then enable owners, designers, and contractors to compare performance on their projects against industry norms. In this direction, some statistical data were selected and analysed from the Input-Output Division of Statistics Canada, and labour productivity indexes were calculated for three segments of the construction industries over the period 1981 to 1991. The resulting indexes shown in Chart 2, indicate substantial variations in the segmental productivity growths. In particular, it appears that labour productivity experienced the lowest growth in the residential sector, whereas a substantial gain was made in road construction. The declining productivity in residential construction could be due to declining labour input growth, which is, in part, a result of falling output growth, and the increasing substitution of capital, materials and services for labour (modularization and prefabrication).

Chart 2. Labour Productivity for Residential, Non-residential and Highway Construction (GDP/Person), 1986=100



To illustrate that productivity in the construction industry could further vary from province to province, some data were taken from the 1989 census of construction industry conducted by Industry Division of Statistics Canada. Provincial productivity indicators calculated are shown in Table 2. The net value of construction and the labour force used for the calculations are also listed. It should be emphasized that the figures in this table are only broadly accurate in showing a wide variation in productivity between provinces. The values for output are net, that is, they are exclusive of the cost of materials used (being composed mainly of wages and salaries), in order to eliminate distortions due to variation in material inputs. In the residential sector, productivity was generally higher in the western provinces in 1989. Output per hour in Alberta, for example, was double that in each of the Maritime provinces. On the other hand, productivity in non-residential, highway, and engineering construction was much higher in the three central provinces, Quebec, Ontario, and Manitoba.

The results of the above calculations are a valuable indication of levels and trends of productivity in various construction industries in different provinces of Canada. Such an extended coverage, however, requires much more research in both data development and the refinement of techniques.

Table 2. Provincial Labour Productivity for Construction Industries in Canada, 1989

	Nfld	P.E.I.	N. S.	N.B.	Que.	Ont.	Man.	Sask.	Alta	B.C.	Canada
Residential											
Net Value of Output (thousands of dollars)	55,034	20,309	144,526	95,255	2,102,642	5,337,994	209,599	140,001	696,592	1,126,562	9,950,977
Labour wage hours	855	248	1,784	1,210	11,189	22,680	951	857	4,015	4,661	48,853
Output per hour ($)	64	82	81	79	188	235	221	163	174	242	204
Non-residential											
Net Value of Output (thousands of dollars)	144,297	42,511	388,290	212,206	3,029,871	6,013,509	388,173	331,728	1,114,306	1,098,046	12,828,805
Labour wage hours	1,379	686	2,522	1,352	15,917	32,802	1,939	2,223	7,000	8,598	74,933
Output per hour ($)	105	62	154	157	190	183	200	149	159	128	171
Highway											
Net Value of Output (thousands of dollars)	143,725	18,389	100,595	92,398	822,771	1,465,337	111,523	119,088	579,402	537,317	4,025,004
Labour wage hours	2,339	615	2,659	2,173	10,236	18,452	2,342	2,156	7,631	6,896	56,074
Output per hour ($)	61	30	38	43	80	79	48	55	76	78	72
Engineering											
Net Value of Output (thousands of dollars)	38,820	10,657	87,271	84,780	1,267,848	1,687,200	187,179	156,061	1,058,717	624,961	5,327,129
Labour wage hours	654	316	1,616	1,955	14,548	23,863	4,456	3,008	17,546	7,190	76,877
Output per hour ($)	59	34	54	43	87	71	42	52	60	87	69

4. Productivity Adjustment in Construction Price Indexes

Indexes currently produced at Statistics Canada for different sectors of the construction industry are either of input cost type or output price type. The input cost index, which measures changes over time in the cost of input resources to the construction, is based on composite indexes of wage rates and material prices, unadjusted for changes in productivity and gross profit margin. This method assumes that changes in wage rates and material prices result in changes in prices of the final products.

On the other hand, the output index attempts to measure changes in transaction prices and takes into account, implicitly, the effects of changes in construction productivity and market conditions. It is of course difficult to construct an output price index for an industry such as construction which produces heterogeneous products. The usual procedure in such cases is to measure output and its price indirectly. For the production of output price indexes, Statistics Canada uses an estimation approach, referred to as 'Model Price Technique', in which changes in contractors' selling prices are estimated over time for building components and a specified quantity of materials in place. All construction costs are therefore indirectly reflected in the resulting indexes. In particular, since an independent measure of productivity cannot be obtained, some index components are adjusted for labour productivity implicitly on the basis of contractor and subcontractor surveys. Construction index methodology has been described in detail elsewhere (Mohammadian and Seymour, 1995).

In this paper, we suggest formalizing the productivity adjustments to the input factors that are used in the compilation of output indexes, so that these indexes could be more impartial and enduring. For this purpose, an input productivity index is computed for the non-residential construction industry, based on the approach initially suggested by Dacy (1964). Since the share of labour is known for each period, Dacy's modified input productivity formula can be used to derive an input productivity index that reflects changes in productivity. A comparison of the input and input productivity indexes will then provide an estimate of productivity changes in non-residential construction. This approach is summarized as follows:

The input cost index is currently computed as a weighted average of price indexes of materials and labour as follows:

[1] $$P' = a_W\ w' + a_M\ m'$$

where

P' = input cost index,
m' = material price index,
w' = wage rate index, and
α_W and a_M are the wage and materials weights.

The input productivity index proposed by Dacy introduces an adjustment to wage rates for productivity:

[2] $P' = \alpha_W (w'/z') + a_M m'$

where

z' is the labour productivity index.

Therefore, an increase of labour productivity deflates the wage index in [2]. When there is no change in labour productivity, [2] becomes identical with [1].
The simplified version of equation [2], subsequently derived by Dacy is then:

[3] $$P' = \frac{a_M m'}{1 - a_W \frac{s_1}{s_o}}$$

where

α_W and a_M are the base year weights for the wage and materials components,
s_1 is the labour's share in period 1, and
s_o is the share in the base year.

This equation is of great practical potential because it eliminates the necessity of knowing anything about the value of output, person-hours of labour, or the wage rate. Therefore, it can be used to the advantage of the construction industry, by obtaining productivity adjusted price movements for various segments of the industry. All that is needed is the amount paid in wages, i.e. the labour share for each period, the total cost of construction, and the prices paid for materials.

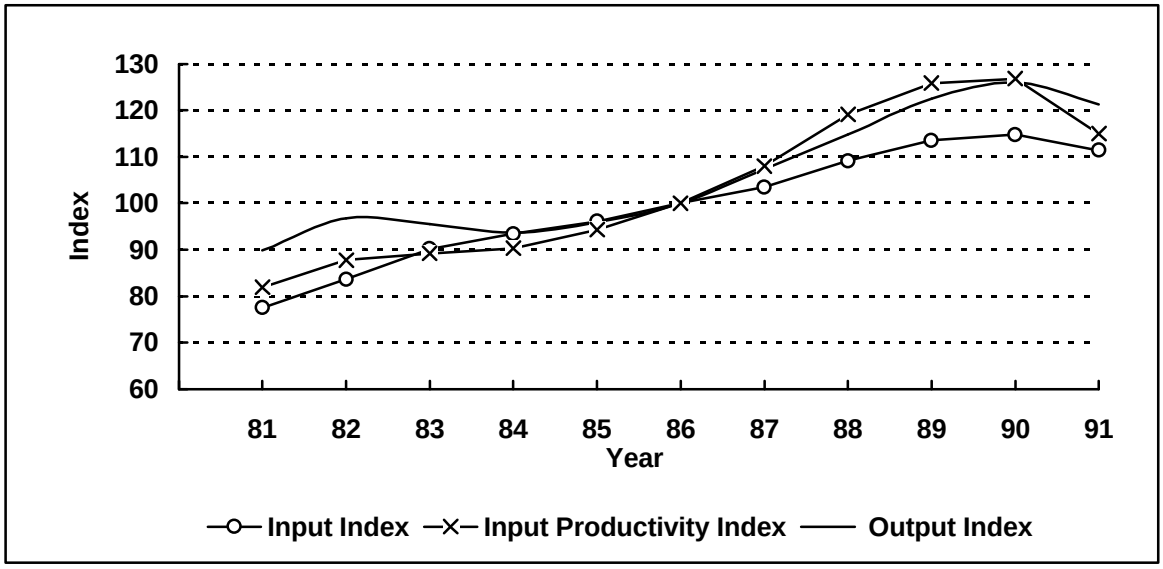
Equation [3] has been used to calculate an input productivity index for the non-residential construction over the period 1981 to 1991. The results are presented in Table 1, where they are compared with the corresponding input cost and output price indexes, with the base year of 1986. The fixed weights a_W and a_M were taken to be 0.47 and 0.53 respectively, which are the current established weights used in the production of input indexes for non-residential construction. The share paid to labour, s, was taken directly from the statistics provided by the Input-Output Division of Statistics Canada.

The last row of Table 1 gives the rate of price increase for the indexes. First, it is noticed that there is not a considerable difference in the rate of price increase between the indexes. The average increase is 3.73% per year for the input cost index and 3.59% for the input productivity index. On the other hand, the rate of increase is only 3.13% per year for the output price index indicating that the input cost index overestimates the real rate of price increase in the non-residential construction.

The reason for this is that when productivity increases, it tends to lower the price, which is reflected in the output price index but not in the input cost index.

To investigate whether the input productivity index gives a closer approximation to the output price index than the input cost index, a visual comparison of the three indexes is made in Chart 3. It is observed that the input productivity index gives a better approximation to the output price index and does not have much bias of underestimation.

Chart 3. Input, Input Productivity and Output Indexes for Non-residential Construction, 1986=100



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.

5. Summary and Conclusions

Accurate productivity measures are essential to construction industry participants and to those who set and implement government policy. Although there are a variety of productivity measures available for the Canadian construction industry, they do not provide the necessary information for policy makers, nor are they based on the breadth of information to which the federal government has access. For these reasons we have focused on how information produced at the federal government level can be enhanced.

Currently, construction productivity measures are produced at the aggregate level. We suggest two methods of further categorizing this information that would more closely reflect the

needs of the various audiences. The first method consists in disaggregating the information by industry segment, and the second is categorizing the information geographically. However, the challenge is to accurately and consistently reach these goals while minimizing data collection.

The selected price index meets these goals and is an improvement over previous indexes in two ways. First, it accounts for changes in labour productivity that would otherwise be hidden within the index, and second, it can be applied to industry segments and to industry regions with a minimum amount of data requirements for its computation. Sample statistics indicate that this approach results in useful information that has practical significance. Further research is, however, necessary on this approach to verify and expand its application and to select the appropriate methods of data collection and analysis.

Acknowledgments

The authors would like to express their appreciation to the people who provided some of the data used in the preparation of this paper: René Durand and Jean-Pierre Maynard from Input-Output Division, and M. Kaba from the Industry Division of Statistics Canada.

References

Committee for Economic Development (1983) Productivity Policy: Key to the Nation's Economic Future, 477 Madison Avenue, New York, NY, USA.

Dacy, D.C. (1964) ‘A Price and Productivity Index for a Nonhomogeneous Product’ Journal of the American Statistical Association, pp. 469-480.

ENR (1995) ‘Market Trends’ The McGraw-Hill Construction Weekly, New York, NY, USA.

Hanscomb (1995) Construction Cost Trends, Hanscomb Consultants, Toronto, Ontario, Canada.

Means (1995) Building Construction Cost Data, City Cost Indexes, R.S. Means Company, Inc., Kingston, MA, USA.

Mohammadian, R. and S. Seymour (1995) An Analysis of Some Construction Price Index Methodologies, Statistics Canada, Prices Division Analytical Series, Catalogue No. 62F0014MPB, No. 2

Revay and Associates (1981) Construction Productivity Standards, Province of Alberta, Report commissioned by Construction Owners Association of Alberta.