THE PRODUCTIVITY OF THE CONSTRUCTION INDUSTRY: MEASUREMENT OF INPUTS AND OUTCOMES IN A DYNAMIC SYSTEM.

G. de Valence

Abstract
The poor productivity record of the construction industry from the mid-1960s on made the performance of the industry an issue. This led to a number of inquiries and government policy initiatives across the OECD. The explanation of the productivity slowdown in the construction industry is typically sought in characteristics of the data collected. This paper summarises endogenous growth theory, which sees economic growth and development driven by technological innovation, learning and the application of knowledge. Some of the implications for analysis of productivity trends in construction of the new growth theories are considered, as is the significance of the issues identified.

Keywords: Construction, productivity, statistics, economic growth

Produktivnost u gradevinarstvu: mjerenje ulaza i izlaza u dinamičnom sustavu

Sažetak
Niski rezultati u produktivnosti u gradevinarstvu od srednjih 1960-ih do danas učinili su uspješnost te grane gospodarstva ozbiljnim pitanjem. To je dovelo do određenog broja istraživanja i strateških inicijativa od vlada širom OECD. Tipično je smanjenje produktivnosti u gradevinarstvu obrazložiti karakteristikama skupljenih podataka. Rad daje pregled teorije endogenog rasta, koja vidi ekonomski rast i razvitak kao potaknut tehnološkim inovacijama, učenjem i primjenom znanja. Razmatraju se neke implikacije

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Introduction

Productivity is one of a group of words that refer to economic and financial performance, at the level of both the firm or workplace and the country. Other words in the group include efficiency, competitiveness, value adding and effectiveness. The concept should encompass the allocation and efficient use of resources as well as performance relative to competitors, and can utilise a range of different measures such as hours worked, dollars, physical units, indexes and ratios of inputs and outputs, and service and quality indexes.

The poor productivity record of the construction industry from the mid-1960s made the performance of the industry an issue for clients and other stakeholders. Industry performance also has important consequences for national economic growth and competitiveness, and the productivity slowdown led to a number of inquiries and government policy initiatives across the OECD.

This paper firstly looks at the concept of productivity and problems associated with measurement of rates of productivity growth. The explanation of the productivity slowdown in the construction industry and the industry's comparatively low productivity growth rates is typically sought either in specific characteristics of the construction industry and its business processes or in characteristics of the data collected by the national statistical agencies following the UN System of National Accounts.

Secondly, the paper summarises the main ideas proposed by some of the theorists working on endogenous growth theory, which sees economic growth and development as driven by technological innovation, learning and the application of knowledge. Some of the implications for analysis of productivity trends in construction of the new growth theories are considered, as is the significance of the issues identified by the new approach to construction productivity and the implications of knowledge based, technology centred growth models.

2 The productivity slowdown

In the 1970s, even before the oil prices increases on 1973-74, the rate of productivity growth across the OECD decreased to around half the rate of the 1960s. As one of the most important sources of economic growth in developed economies the productivity slowdown quickly became a major issue for researchers and policy makers, and has continued to be a focus of macroeconomic research and debate since [1].
The rate of growth of productivity in the construction industry, in Australia and elsewhere, has lagged that of other industries for at least three decades [2], and this poor relative performance led to an extensive research program, particularly in the US and UK, but also in Australia, Japan, Singapore and Europe. In the UK research was led by Hillebrandt and NEDO [3]. In the US the Business Roundtable [4], later the Construction Industry Institute, and the Building Research Board [5] focused on construction productivity.

Table 2 below shows the Australian productivity record at the industry level for the business (ie, private) sector, given for labour, capital and total factor productivity. The data is broadly comparable with other OECD economies, with the proviso that construction productivity in Australia had a lower growth rate than in the UK, US and Europe [6]. The relatively poor productivity growth rate of construction is emphasised by the negative growth in measured labour, capital and total factor productivity growth.

Table 1. The slow-down in productivity growth

<table>
<thead>
<tr>
<th>Exponential rates of growth</th>
<th>Period</th>
<th>OECD</th>
<th>USA</th>
<th>Japan</th>
<th>UK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Europe</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>GDP</td>
<td>1960-73</td>
<td>0.046</td>
<td>0.040</td>
<td>0.092</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>1973-85</td>
<td>0.019</td>
<td>0.023</td>
<td>0.038</td>
<td>0.013</td>
</tr>
<tr>
<td>Employment</td>
<td>1960-73</td>
<td>0.004</td>
<td>0.019</td>
<td>0.013</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>1973-85</td>
<td>0.001</td>
<td>0.019</td>
<td>0.008</td>
<td>-0.002</td>
</tr>
<tr>
<td>GDP per person employed</td>
<td>1960-73</td>
<td>0.042</td>
<td>0.021</td>
<td>0.079</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>1973-85</td>
<td>0.018</td>
<td>0.005</td>
<td>0.029</td>
<td>0.015</td>
</tr>
</tbody>
</table>

### Table 2. Productivity growth rates, Australian business sector (per cent per annum)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Labour productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>4.3</td>
<td>2.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2.6</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td>Electricity Gas Water</td>
<td>5.1</td>
<td>3.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Construction</td>
<td>0.6</td>
<td>1.2</td>
<td>-1.0</td>
</tr>
<tr>
<td>Wholesale retail trade</td>
<td>0.9</td>
<td>1.4</td>
<td>-0.3</td>
</tr>
<tr>
<td>Trans. Stor'ge.Comm'n</td>
<td>3.9</td>
<td>4.8</td>
<td>2.7</td>
</tr>
<tr>
<td>Recreation</td>
<td>-0.1</td>
<td>0.5</td>
<td>-1.5</td>
</tr>
<tr>
<td>Finance</td>
<td>1.4</td>
<td>1.9</td>
<td>0.2</td>
</tr>
<tr>
<td>Total business sector</td>
<td>2.0</td>
<td>2.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Capital productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>-2.1</td>
<td>-1.8</td>
<td>0.3</td>
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</tr>
<tr>
<td>Trans. Stor'ge.Comm'n</td>
<td>1.2</td>
<td>2.3</td>
<td>0.2</td>
</tr>
<tr>
<td>Recreation</td>
<td>-2.7</td>
<td>-1.6</td>
<td>-3.7</td>
</tr>
<tr>
<td>Finance</td>
<td>-2.7</td>
<td>-3.2</td>
<td>-2.3</td>
</tr>
<tr>
<td>Total business sector</td>
<td>-0.8</td>
<td>-0.7</td>
<td>-1.1</td>
</tr>
<tr>
<td>Total factor productivity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mining</td>
<td>-0.1</td>
<td>-0.4</td>
<td>1.7</td>
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<td>1.7</td>
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<td>1.1</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Source: ABS Cat. Nos. 5204.0, 5222.0, 6203.0, 6204.0.

3 The measurement of productivity

Changes in productivity reflect changes in efficiency in converting inputs into outputs over a period of time. At the national level, productivity growth drives economic growth and development, and indicates a potential for improved material standards and increases in
the society's general welfare. Gains from improved productivity are distributed in three ways: through prices, which rise more slowly than they otherwise would do and so benefit all sectors of the economy; through wage increases or improvements to employee benefits; and through improved business profits, leading to increased investment and a higher level of employment.

The dominant model of economic growth is the standard two sector (capital and labour) neo-classical model in which the determinants of growth are exogenous, with growth due to advances in knowledge or technological progress which are independent of activities of economic agents and government has no direct role to play. This model has been challenged by new endogenous growth theories, which attempt to incorporate the determinants of growth into the model.

The standard neo-classical model is based on the assumptions of perfect competition in all markets and only two homogeneous and substitutable factors of production: labour (L) and capital (K). There are constant returns to scale and diminishing returns to any one factor of production. Each factor receives a return equal to its marginal product, so that the total earnings of capital and labour exactly absorb the total output. The labour force is homogeneous, equal to the population, and determined outside the model (ie. exogenously). The production function gives output Q as a function of the capital and labour inputs K and L, so that, in period $t$:

$$Q_t = F(K_t, L_t).$$

The determining factor in long run economic growth is the growth in the labour supply, which allows aggregate growth to take place but does not result in growth in per capita output. More sophisticated models introduce technological progress into the model, as a term representing total factor productivity growth (ie. combined capital and labour productivity. When this happens, technological progress and the growth in the labour supply jointly determine the aggregate growth rate but technological progress also allows growth in per capita output to take place. Like the growth in the labour supply, the rate of technological progress is assumed to be determined outside the model.

Researchers using the neo-classical framework have typically focused on the measurement problems associated with the Cobb-Douglas production function above [7]. Factors involved in the estimation of productivity growth rates include technical advancement, usually through capital investment, the ratio of capital (plant and equipment) to labour, management quality, the quality of labour and workforce skill formation through increased training. In particular, the statistics used by the Australian Bureau of Statistics (ABS) and other agencies to estimate gross product and industry inputs are subject to the general problems of sampling and distribution, but are also affected by the choice and composition of deflators used to produce constant price estimates of output [8]. All these factors have associated data problems, making productivity measurement fraught with difficulties. Among the difficulties commonly cited are:

- the scope for measurement errors in inputs and outputs;
- statistical conventions in collecting and defining data;
- changes in quality and composition of output and input;
- the effect of economies of scale and the business cycle;
For analysis of productivity the industries in the OECD national accounts tables can be divided into two groups. The first group consists of industries for which the data provides a satisfactory measure of real output which can be combined with measures of real input to provide satisfactory measures of productivity. Real output and real input are the constant price estimates of their values, i.e. adjusted for the effect of inflation. This adjustment involves assumptions about the causes and effects of price increases that can lead to estimation errors in constant price series.

The second group consists of industries which do not provide satisfactory measures of real output. For studying movements in productivity it is necessary to have measures of output which are derived independently from measures of inputs, and for a significant part of the Australian economy satisfactory measures of real output are not available. The measures used by the ABS in estimating real GDP movements in output in two industries, finance and public administration and defence, are no more than the movements in hours worked. In two other industries, construction and community services, the ABS deflators used in the definition of real GDP do not properly reflect the role of technological change or variations in the costs of capital. Altogether the activities in this second sector account for about a third of the ABS measure of real GDP. Industries in this second sector are: Construction; Finance; property and business services; Public administration and defence; Community services.

The very low rate of growth of labour productivity in this second sector reflects the conventions adopted in measuring output in these industries. The lack of growth in labour productivity in these industries depresses aggregate labour productivity growth for the economy as a whole [9].

An issue affecting estimates of labour productivity is the complex question of measuring the rate of capital accumulation at the industry level. Most labour productivity gains are due to technological gains in the form of increased capital intensity at the firm, industry, or economy level. In Australia, throughout the 1980s the average annual rate of capital accumulation increased steadily, whilst the growth of the capital-labour ratio fell in the latter half of the 1980s, a situation found in other countries over the period. The slowdown in the rate of growth of the capital-labour ratio reflects a combination of two principal factors behind the rapid growth in employment from 1983-84 to 1988-89: the strong cyclical expansion of the economy, and a change in relative factor prices resulting from falling real wages and rising costs of capital with higher interest rates. However, the expansion of the number of persons employed in the construction industry in Australia was not a result of declining real labour costs, but due to the dramatic increase in the level of building activity to record highs over the decade.

Given the range, depth and extent of these data and measurement problems it is not surprising that many researchers have concentrated on them in their attempts to explain the productivity slowdown, as Englander and Mittelstadt did in their influential study [1], and Maddison [10] in his.
4 Building industry data problems

Through the system of national accounts a wide range of data is available, such as output (GDP), employment and industry activity levels, such as retail spending or car registrations. The building and construction industry, however, does not have an accurate estimation of its output, being measured as the sum of constant price estimates of private and public fixed capital expenditure on dwellings, on non-residential building, non-building construction, and maintenance expenditure. Both public and private building and construction estimates are obtained by deflating current price figures by input price indices. Deflation by input price indices does not produce suitable estimates of output at constant prices and, given the extensive use of input price indices as deflators in estimating the constant price of output for the construction industry, productivity measurement for this industry is problematic, to say the least [11].

The employment data that is the source of persons employed and hours worked figures has its own problems, associated with changes in the sample and methodology over time. The different series can be reworked to give a long-run series, but this involves a number of assumptions about changes in employment patterns. Similarly, the allocation of employment in building industry trades to sectors within the building industry cannot be done with any precision.

In order to fully understand the dynamics of the construction industry there has to be disaggregation of the data beyond the level of the industry. The main divisions in the industry in the statistical data available from the ABS are between the residential building industry and the rest of the construction industry. There are however three distinct sectors in the building industry: residential, non-residential, and non-building or engineering construction. The data necessary for productivity analysis, constant price estimates of output, hours worked and persons employed, is not available for each of these sectors [12].

Specific problems associated with the data used in analysing productivity in the construction industry include:

- the deflator used to adjust for price changes will, if indices for labour and material costs are used instead of output price indices (which are not available), systematically overstate the rate at which prices increase and underestimate growth in output and productivity
- the fact that construction work done by establishments not classified as being in the construction industry is excluded from the output data
- employment data may include hours worked on some of these excluded projects and inflate the industry's total hours worked, also there is an element of double counting in the number of people employed due to part-time workers with more than one job in the industry
- the inadequacy of estimates of capital stock, capital utilisation and other input factors.
At the industry level, other factors that affect industry statistics and are contributing to a decline in measured productivity include:

- changes in the mix of residential, non-residential and engineering construction, or shifts in the composition of the industry’s output over time
- changes in the amount of capital equipment used on-site per worker (capital intensity of the production process)
- structures becoming more complex
- increasing industrialisation of building and greater use of off-site fabrication
- price effects of the boom-bust cycle on the measurement of output and value-added of the construction industry
- understatement of the real output of the construction industry, which does not include all work done on maintenance, alterations and additions.

5 New growth theory

The divergence between the standard approach and the new endogenous theories of economic growth is that advances in knowledge are seen as the direct result of activities of economic agents, and the new models combine these advances with public good aspects of knowledge, which produce positive externalities where imperfect competition resulting from economics of scale and specialisation in production exists.

Economic development is looked at as a dynamic process, occurring discontinuously over time. The introduction of an innovation by one entrepreneur leads to diffusion of the knowledge and affects other entrepreneurs’ decisions about their own production possibilities. Eventually the pace of diffusion associated with that particular innovation will slacken and so will the rate of economic development. Because of the search for profits, another innovation is sure to come along after a period of time, allowing the development process to pick up pace again. In this way the cycle keeps repeating itself.

The new endogenous growth theories focus on the linkage between technological progress (or the application of new knowledge in Schumpeterian terms) and economic growth. They do this by incorporating the linkage into their models of growth, and thus differ markedly from the standard neo-classical model where technological change, although recognised as the agent of growth, is determined outside the model.

In the new theories, economic growth is associated with four factors which distinguish it from the neo-classical model: growth is the result of deliberate rational, optimising decisions by investors, producers and consumers; investment behaviour is in physical capital, human capital, research and innovation; there is imperfect competition and the presence of externalities [13].

The new growth theories focus discussion on influences on economic growth that have often been ignored or overlooked, and attempt to explain how these influences operate. Endogenous growth theories emphasise the public good characteristics of knowledge, which are essential because they result in externalities. The nature of the mechanism through which knowledge is transmitted is fundamental in determining which industries gain or lose through advances in knowledge and whether or not convergence of incomes between industries will occur.
Also, the impact of economic incentives on the development of new technology makes clear the endogenous nature of the growth process. In practice new investment does not merely reduplicate old capital (i.e. move along the production function) but embodies technical progress, so investment in endogenous growth models shifts the production function to a new level. The act of investment, in innovation and human and physical capital, appears to be important for generating the externalities that lead to growth. The primary factor influencing the amount and type of investment undertaken by investors is the private return it generates, and additional growth will be generated if this investment results in externalities [14].

The distinction between the benefits of knowledge that can be appropriated by the knowledge-producing firm and the benefits that become a public good is fundamental to the new growth theories. Government policy with respect to patents, copyright and property rights to knowledge will have some effect on this balance.

The main area where governments might be able to act to increase growth in areas relating to the diffusion of knowledge is openness to trade, capital and technology movements is associated with a higher growth rate, although this can be explained by the standard analysis of the benefits from reduced distortions to trade and capital flows. New growth theory would argue that it is also the result of knowledge spillovers between countries that occur as a result of openness.

To the extent that the externalities relating to an industry are confined to particular countries, the presence of that industry can give a country an advantage that will be difficult to overtake. Related industries seeking to appropriate the externalities will be attracted to the country, resulting in even greater growth and the development of 'growth poles'.

Increasing openness in world trade, capital and technology movements reduces the likelihood that externalities can be confined to particular countries and that 'growth poles' will remain unchallenged over time. At the same time, this openness increases opportunities for greater economies of scale and specialisation of firms in the established 'growth poles'.

6 Research and development and construction technology

Numerous researchers have explored the relationship between productivity, research and development (R&D) and innovation, in particular Griliches [15], Griliches and Lichtenberg [16] and Scherer [17]. This research found that investment in research and development has a significant and positive affect on the growth rate of productivity. This implies that the role of R&D in the slow down of the productivity growth may be important, however the effect of R&D is most pronounced where technological opportunity is high. The connections between product development, choice of technology and growth and productivity are all areas where there have been major problems in measurement of prices and output, making hard conclusions almost impossible to reach. Nevertheless, the general results of this research can be applied to the construction industry.

The relationship between R&D, productivity and international competitiveness cannot be precisely pinned down, however the Japanese contractor's success in winning a greater
The share of foreign contracts has rewarded their commitment to R&D, which delivers technological innovation and competitive strength in global markets.

Between 1984 and 1990 the share of the global market in foreign construction contracts won by American contractors fell from 38 percent to 36 percent, while the share won by European contractors rose from 38 percent to 43 percent, and the share won by Japanese contractors rose from 9 percent to 14 percent of the total. The combined share of the three rose from 85 percent to 93 percent. This trend is attributed to the increasing importance of technology [18].

The commitment of the Japanese construction industry to research and development far exceeds that of any other country. More than 25 of the 30 largest Japanese construction firms maintain R&D centres and 10 firms employ more than 100 researchers. The big six Japanese construction firms spend 1 percent of contracts awarded (perhaps 60 percent of net profits) on R&D. About half of that expenditure would be classified as R&D in America, where the six largest construction firms were estimated to have spent only 0.04 percent of sales on R&D in 1985 by CERF [18].

A 1986 report by the U.S. Building Research Board went so far as to suggest that R&D expenditures could act as a proxy for the conventional labour productivity measures traditionally used for the construction industry[5].

7 Conclusion
Endogenous theories of economic growth are important because they focus on the factor that is the key to long-term economic growth, increased productivity from new knowledge produced through investment by rational, profit-seeking economic agents. They also explain growth through the role of certain externality-generating activities and linkages between different sectors of the economy. The nature of the mechanism through which knowledge is transmitted is fundamental in determining which industries gain or lose through advances in knowledge and whether or not convergence of incomes between industries will occur. These ideas are significant, not just in finding new explanations for the construction productivity slowdown, but also in the context of increasing globalisation and the emergence of an international construction industry. There is also the scope for competitive advantage that these ideas reveal.

One of Scott's [13] conclusions was that: “labour productivity tends to grow at the same rate in all industries in a given economy in a given time period. This conclusion does not hold for different time periods ... nor does it apply to different economies”. If this is the case the productivity record of the construction industry would indicate that the industry has not, so far, been able to unlock the productivity gains found in other industries, but there is no insurmountable barrier to it doing so.

Application of the new growth theories to the productivity slowdown in the construction industry offers a range of explanations beyond the debate about the quality of the statistics and data available to researchers. In particular, the possibility that construction as an industry generates few knowledge-based externalities should be investigated further.
Groak [19] describes technical precedent and tried and tested methods of building as 'robust technologies', and suggests that traditionally these have typified the building process. He uses the term 'fragile technologies' to describe 'methods of building which are or have become sensitive to errors of design, manufacture, assembly or use. They have moved beyond the robust limits', and suggests that an increasing proportion of both structures and the processes used to deliver them are now fragile technologies, with comparatively little of the tried and tested methods of building left.

Technological change plays a significant role in the competitive environment throughout the design and construction industry, where the level of technology used is increasingly important. Therefore the research culture of the industry, and its role as a transmission mechanism for knowledge and information, is coming under scrutiny.

This does not, however, support the argument put forward by Seymour and Rooke [20]. In their discussion of the research paradigm in building and construction they attack the 'rationalist' approach, based on positivist methodology and fundamental to the hard sciences, as not being suitable for "making assessments of social processes" such as the construction industry and its organisational structure and relationships. Their alternative is an 'interpretativist' approach, where the aim is to report on the perspectives of the participants in particular settings. This type of industrial sociology may provide interesting insights into industry relationships, but will not explain or suggest solutions to the industry's low rate productivity growth and constrained use of new technology. In particular, construction needs to, in Rosenberg's phrase (21), get inside the black box of technology and its impacts on the construction process.

One area where the two approaches to growth theory agree is the need for an efficient economy. In both the standard neo-classical theories and new growth theories the removal of distortions, particularly areas of market failure like environmental management, pollution control and urban design, from the economy is seen as a positive move towards maximising income. The new growth theories point to a number of reasons why market forces alone might not result in the highest possible long-term growth path.

While there is still considerable controversy and theoretical debate, the new models do provide important insights into the sustained growth of some countries and industries relative to others with comparable initial levels of income and technology. To date, the models have proved difficult to test empirically and it is not yet clear that any of the models provide an adequate explanation of the growth process at either the country or industry level.

The applicability of endogenous growth theory to the analysis of construction industry productivity and development needs to be tested. These theories appear to offer a range of new research directions and provide new models of the industry development process, and therefore may deliver new explanations for old problems. It seems that a knowledge centred, technology driven industry model may be the most relevant to the challenges currently facing the construction industry, and those that research the industry.
8 References


