

An Input-output Table Perspective on Measuring Construction Productivity

Deakin University

O Chunlu Liu¹

Deakin University

Yu Song²

Nagoya University

Yoshito Itoh³

Abstract: In the field of construction economics, input-output analysis based studies have attracted a lot of interest from the academics and researchers. The wide efforts are to carry out analyses and comparisons of economic indicators in construction sectors across countries and years. There has been little research modelling the construction productivity using input-output tables. This research takes advantage of the input-output analysis to develop a perspective for determining the productivity of an industrial sector. The developed quantitative formulas are fully based on the economic indicators generated from an input-output table. Using the newly published OECD input-output database, historical analyses and comparisons are carried out to indicate the differences of productivities of the construction sectors in Australia and Japan.

Keywords: Australia, construction sector, input-output database, Japan, productivity

1. INTRODUCTION

Over many decades, the construction sector has been recognised to form a vital part of national economics with a higher link with other sectors worldwide. In Australia, the construction sector has directly contributed approximately between 5-6% to gross domestic product according to the Royal Commission into the Building and Construction Industry (2002). In Japan, the construction sector has also played an important role in the economic development (Liu et al. 2003). The research on the construction productivity measurement has attracted a lot of research interest (Bon 2000, Durand and Vezina 2003, Parham 2004). Productivity measurement of the construction sector establishes a connection between the micro and macro levels of the economy and helps answer questions about the

contribution of individual industries to the productivity growth. On the other hand, improved international comparisons of the construction sector productivity are also needed in order to achieve a better comprehension of the structural change, technological progress, comparative advantage and competitiveness (Gullickson and Harper 1999). Therefore, a cross-national comparison between Australian and Japanese construction industries will add values to both research and practice.

Early research efforts formulated productivity measurement in a production function context. Diewert (1976) developed a production theoretical approach to measure productivity and integrated the theory of the firm, index number theory and national accounts. The productivity concept was adopted and a set of formulae were developed for productivity after assuming competitive input

¹Senior Lecturer, School of Architecture and Building, Deakin University, Australia, chunlu@deakin.edu.au, +61-3-52278306

²PhD Candidate, School of Architecture and Building, Deakin University, Australia, yso@deakin.edu.au, +61-3-52278383

³Professor, Department of Geotechnical Engineering, Nagoya University, Japan, itoh@nui.nagoya-u.ac.jp, 052-7892737

market and constant returns to scale in production. The research led to the publication of productivity measures by the USA government in 1983. Jorgenson et al. (1987) linked these formulae to the economic growth via investigating the relationship between productivity and post-war USA economic growth. Gullickson and Harper (1999) carried out a productivity analysis and concluded that the productivity trend is a better indicator of tracing technical change, identifying efficiency and inefficiencies and recognizing economies scale of a sector. Parham (2004) investigated productivities of all Australia's industries from 1964 to 1999 and commented that complementary research at the aggregate, industry and micro level is needed. Durand and Vezina (2003) worked out the construction's productivity in Canada from 1961 to 1997.

Many different methods of productivity measurement, calculation and interpretation were adopted in previous international comparisons (Diewert 1976, Kravis 1976, Islam 1999). Kravis (1976) surveyed the majority of research based on the international comparisons of productivity up to 1976 and compared the differences of productivity of agriculture, mining, construction and manufacturing sectors. Diewert (1976) reviewed ten classes of multilateral methods from both the viewpoint of the axiomatic approach and the economic approach in order to make aggregate price and quantity comparisons between different countries and regions. Islam (1999) reviewed the time-series approach, the panel approach and the cross-section approach in the international comparison of total factor productivity and concluded that the choice of productivity measures depends on the purpose of productivity measurement and, in many instances, on the availability of data. The productivity and economic growth in Japan and USA from

1960-1973 are compared by Jorgenson (1988). Ark et al. (1993) explored the comparative productivity performance in manufacturing of three countries: Germany, Japan and the United States since 1950 using detailed information from censuses of manufactures for each country. Bernard and Jones (1996) examined the productivity convergence for 14 OECD countries during 1970-1987. Their research just focused on the productivity convergence, and the construction sector was not stated individually. The major finding is that manufacturing shows little evidence of either labor productivity or productivity convergence, while other sectors, especially services, are driving the aggregate convergence result. Moreover, Ark and Monnikhof (1999) dealt with measurement of productivity differentials in manufacturing for five countries, namely Canada, France, Germany, the Netherlands and the US. Gu and Ho (2000) finished a consistent international productivity comparison of the patterns of growth in Canadian and USA manufacturing sectors over the period 1961-1995. Obviously, their studies more likely focus on the manufacturing sector rather than construction sector.

In the construction industry, several types of productivity concepts have been developed so far, which are mainly based on the involving factors such as labour and capital (Liberda et al. 2003, Zhi et al. 2003). There has been little research modelling the construction productivity using input-output tables although they have been widely applied into diversified research fields of construction economics. This research aims to develop an input-output table perspective for determining the construction productivity. Therefore, the input-output analysis is briefly discussed in the next section. Section 3 discusses the research methodology. Section 4 introduces the economic indicators that are calculated from

an input-output table and are to be used to formulate the productivity indicators in Section 5. The newly published Organisation for Economic Co-operation and Development (OECD) input-output database is adopted as the data source of this research, and Australia and Japan are considered as the comparative countries. As the input-output tables provide only the historical data, these economic indicators as well as the productivity indicators show the historical trends, not the forecasting in the future. Because it is widely recognised that the decline of the construction sector sets in with economic maturity (the more developed the economy, the smaller the shares of its construction sector), these shares reflect the future economic development.

2. OECD INPUT-OUTPUT DATABASE

Input-output tables describe the supply and disposition of the products of an entire economic system for a particular period (O'Connor and Henry 1975). They give a fully articulated analysis of the economy, an apparent illustration on the relationship between producers and consumers, and the clear interdependence of industries. The balances also show the purchases of those products used in the production process and therefore reconcile the output, income and expenditure measures of national economy. What is more, the tables also provide a framework to assess the direct, indirect and induced changes on the whole economy when the demand for a single product increases or decreases. The row total for an industry in an input-output table is equal to the corresponding column total as the output of an industry is equal to the sum of its inputs.

Despite the importance of input-output statistics, internationally comparable input-output

tables for crossing countries had lacked until the OECD input-output database was published in 1995 (OECD 1995). This database, which can be downloaded free of charge from the OECD website, provides common format input-output tables in both current and constant prices for several times from 1968 to 1990 for ten OECD countries: Australia, Canada, Denmark, France, Germany, Italy, Japan, the Netherlands, the UK, and the USA. According to the website of OECD, the unique features of this database are: (1) the use of a common industrial classification with 36 sectors (including the construction sector) by following the International Standard Industrial Classification (ISIC) version 2; (2) the separation of transaction flows of goods and services by domestically produced and imported ones; and (3) the inclusion of capital investment flow matrices as supporting tables. In October 2000, OECD started to revise this input-output database, but the latest version has not been published so far.

The OECD input-output database also provides a comprehensive data source for comparing structural changes in industrial sectors across diverse countries (Liu et al. 2004, Song et al. 2004). Australia and Japan, located in the same Asia-Pacific area, are selected to be compared in this research. For Japan, this database contains five tables compiled in 1970, 1975, 1980, 1985, and 1990. The four Australian input-output tables were compiled in the reference year 1968, 1974, 1986, and 1989. In order to utilise these data to the extreme, all these tables are applied in the analysis. Under the circumstance that each input-output table is matched to certain a table in the other country in one or two conjunctive years with the exception of the Japanese table in 1980, some particular comparisons reflect the differences of various economic indicators in four eras, 1968 and 1970, 1974 and 1975, 1985 and 1986, and 1989

and 1990. Detailed investigations on the commencement differences of fiscal years in both countries are not taken into consideration in the comparisons. In order to avoid the occurrence of problems generally raised in technology comparisons by non-uniform inflation in 1970s and 1980s, the data in constant prices rather than in current prices are used in this paper.

3. RESEARCH METHODOLOGY

For the convenience of research, the data in the OECD database are grouped and symbolised. The symbols and fundamental structure of the OECD input-output database are illustrated in Figure 1. In the OECD input-output database, the

symbol X_{ij} represents the intermediate flow from sector i to sector j . The total output of the sector is divided into intermediate output X_i and final demand Y_i for its goods and services (consumption, investment, government expenditures, etc.). The total input of the sector is divided into intermediate input X_j and value added V_j , which represents the supply of primary inputs or factors of production needed by the sector (labour, capital, land, etc.). The total output X_i equals total intermediate output plus final demand, and the total input X_j equals total intermediate input plus value added. In terms of national product and income accounting conventions, the total final demand represents gross national product (GNP) and the total value added represents gross national income (GNI).

		Domestic Intermediate output					Total intermediate output	Final demand	Total output
		Sector 1	...	Sector j (Construction)	...	Sector 36			
Domestic intermediate inputs	Sector 1								
	...								
	Sector i (Construction)			X_{ij}			X_i	Y_i	X_i
	...								
	Sector 36								
Total intermediate input				X_j					
Value added				V_j				$Y=V$	
Total input				X_j					

Figure 1: Fundamental Structure of the OECD Input-output Database

The indicators are divided into four groups: the sectoral economic indicators, backward and forward linkage indicators, multiplier indicators and the productivity indicators. The productivity indicators are formulated based on the first three indicators. The formulations and definitions are described in the rest of this section.

3.1 Sectoral Economic Indicators

The sectoral economic indicators show the proportions of the construction sector in the whole economy, including the output to GNP indicator and the input to GNI indicator. The formulas are developed as below:

$$\text{The output to GNP indicator} = Y_i / Y \quad (1a)$$

$$\text{The input to GNI indicator} = V_j / V \quad (1b)$$

3.2 Backward and Forward Linkage Indicators

The backward linkage indicator represents the intermediate to total output ratio of the construction sector. The forward linkage indicator represents the intermediate to total input ratio of the construction sector. These two linkage indicators are formulated as:

$$\text{The backward linkage indicator} = X_j / X_j \quad (2a)$$

$$\text{The forward linkage indicator} = X_i / X_i \quad (2b)$$

3.3 Multiplier Indicators

The output multiplier indicator represents the effect of one monetary unit change in final demand of the sector j on total output of all other sectors. It is the column sum of total input coefficients for an individual sector in the input-inverse matrix, which is also called Leontief inverse matrix (Bon 2000). The input multiplier indicator represents the effect of one monetary unit change in value added by the sector i on the total input of all other sectors. It is the row sum of total output coefficients for an individual sector in the output-inverse matrix, which is also called Ghosh inverse matrix (Bon 2000). Both output and input multiplier indicators are shown as below:

$$\text{The output multiplier indicator} = \sum (I-A)^{-1} \quad (3a)$$

$$\text{The input multiplier indicator} = \sum (I-B)^{-1} \quad (3b)$$

where, the symbol I refers to the identity matrix, and the symbol A stands for the matrix of direct-input technical coefficients. The symbol B stands for the matrix of direct-output allocation coefficients.

3.4 Productivity Indicators

The above three groups of economic indicators

provide a new opportunity theoretically to formulate the productivity indicators of an industrial sector from the input-output table perspective. Three productivity indicators are therefore developed to represent the mutual effects between the construction sector and other sectors, including the sectoral productivity, the intermediate sectoral productivity and the aggregate productivity.

$$\text{The sectoral productivity indicator} = Y_i / V_j \quad (4a)$$

$$\text{The intermediate productivity indicator} = X_i / X_j \quad (4b)$$

$$\begin{aligned} \text{The aggregate productivity indicator} \\ = [\sum (I-A)^{-1} * Y_i] / [\sum (I-B)^{-1} * V_j] \end{aligned} \quad (4c)$$

4. ECONOMIC INDICATORS OF CONSTRUCTION SECTORS

In this section, the sectoral economic indicators, backward and forward linkage indicators and multiplier indicator are discussed and analysed respectively.

4.1 Sectoral Economic Indicators

The gross economic indicators to measure the economic development of a nation basically contain gross national product and Gross national income. The shares of the construction sector in these three economic indicators are calculated for Australia and Japan using the respective tables in the OECD input-output database.

The final demand of the construction sector to total final demand ratio represents the contribution of the construction sector to the gross national product. These ratios in the study period, which are calculated from Eq (1a) and (1b), are shown in Figure 2 for both Australia and Japan, which are

roughly from 12% to 20%. Among the 36 industrial sectors, construction in both Australia and Japan contributed relatively higher percentages to the gross national products in these years. For Japan, in all five years including 1970, 1975, 1980, 1985 and 1990, the total final demand of the construction sector is ranked as the top one and the value is at least one third higher than the value of the second top industry named as wholesale and retail trade. The leadership of the construction sector in the shares in gross national product in Australia is not so dominant. Only in 1968, which is the first input-output table over the comparison period, the construction sector was ranked at the number one industry according to final demands, and the difference over the second contributor, the wholesale and retail trade, was only two percent. In 1989, the construction sector was ranked as the third sector according to the final demands and the differences from the community, social and personal services sector, and the wholesale and retail trade sector were 17% and 4% respectively.

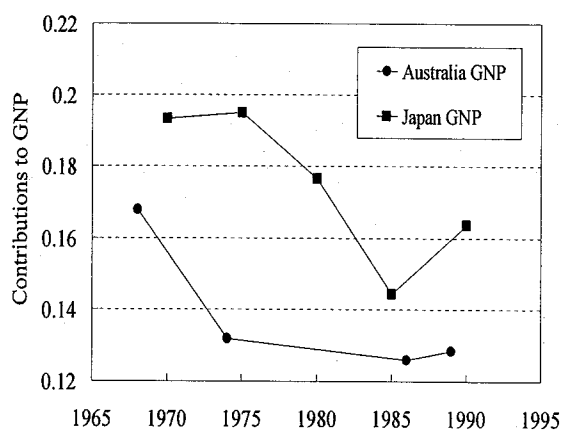


Figure 2: Contributions to GNP

Furthermore, the Japanese construction sector contributed a bigger share than the Australian construction sector over the study period, and the gap was 6.3% at the middle of 1970s. The shares in GNP from the construction sector may be

considered as a sign of the future economic condition. Based on the facts that the percentages are as high as about 13% in 1989 in Australia and 17% in 1990 in Japan and they slightly increased from the previous era, it may be stated that economics in both Australia and Japan would still be increasing in the following years. Apparently, the further discussion on forecasting the economic trends is out of the interest of this paper.

Figure 3 shows the shares in national income of the construction sector in Australia and Japan. With the exception of Japan in 1975, the contribution of each construction sector to the respective national income tends to decline over time and stabilises at a value of about 7-8%.

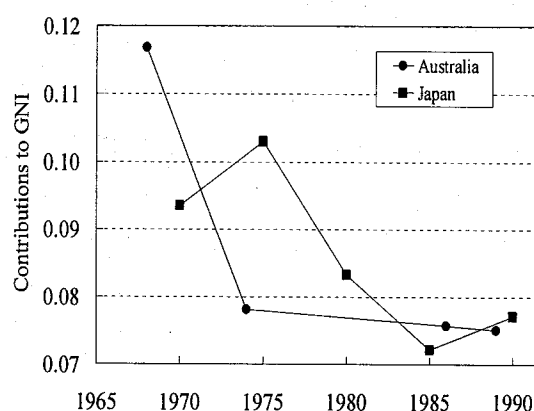


Figure 3: Contributions to GNI

Compared to the shares in Figure 2, the values of national income shares are obviously smaller than the values of GNP, which is a typical characteristic of sectors that produce mainly for final demand and very little for the intermediate use. As a capital-producing sector, the construction sector produces goods and services through assembly, rather than production in the strict sense of word. The production of materials and components that are assembled in the construction process takes place mainly in other industrial sectors such as the sector of metal products. In other words, the construction process

enables other industrial sectors to contribute their goods and services to the national income.

4.2 Backward and Forward Linkage Indicators

The backward linkage indicator, which is calculated from Eq (2a), represents the intermediate to total input of the construction sector in an input-output table. This indicator is also called direct backward linkage indicator or the technical indicator. It roughly reflects the level of industrialisation of the construction process in a country at a certain year. Figure 4 shows that as a capital-producing sector, the backward linkage indicators of the construction sector of both countries are rather high, but they were not ranked as one of highest sectors like most manufacturing sectors such as the motor vehicles sector whose backward linkage indicators in Australia in 1989 and Japan in 1990 were 52% and 62% respectively.

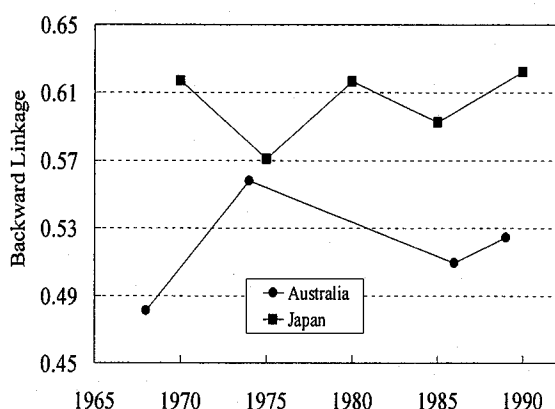


Figure 4: Backward Linkage Indicators

In all these years, the backward linkage indicator value of the Japanese construction sector is comparatively higher than the respective value in Australia, and these values were very close only at the middle of 1970s. This means that the technology degree of the construction sector in Australia is comparatively lower than it in Japan.

Although the indicator values fluctuate from year to year in both countries, the overall trends are slightly to keep these indicator values increasing, which reflect the arising degree to which the construction and manufacturing sectors are interconnected.

Figure 5 shows the forward linkage indicator or the allocation indicator, which is calculated from Eq (2b), represent the intermediate to total output ratio of the construction sector in Australia and Japan. Because the intermediate, and final goods and services in the construction sector are produced through its maintenance and repair, and new construction sub-sectors respectively, the forward linkage indicator value reflects the contributions of maintenance and repair construction sub-sector compared to the new construction sub-sector in the national economic development.

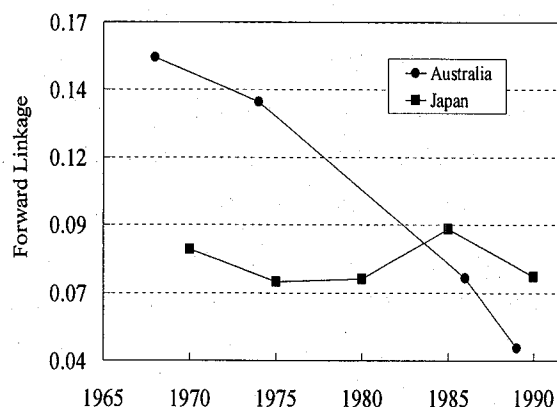


Figure 5: Forward Linkage Indicators

The forward linkage indicator values of the construction sector in Australia significantly tended to decline over these about twenty years. This decrease reflects the arising contributions of the new construction sub-sector as well as the relative decreasing of the maintenance and repair construction sub-sector. It is noticed from this line that the forward linkage indicators of the

Australia's construction sector had an extremely high values in the 1970s and these high values will affect the construction productivity indicators. Further validation of the data source is out of the interest of this paper. The values of forward linkage indicators of the Japanese construction sector waved slightly between 0.07 and 0.09 and did not show a clear changing track over the study period.

4.3 Multiplier Indicators

In addition to direct forward and backward linkage indicators, the demand (input) and supply (output) multipliers represent the inter-sectional effects. The output multiplier, also called a total backward linkage indicator, measures the total effect of a monetary unit change in final demand for the goods and services of a given industry on the output of all industries. It sums all the intermediate transactions over all stages of production during the construction production process. Figure 6 shows the output multipliers of the construction sectors in Australia and Japan in the study period as per Eq (3a). The output multipliers for the construction sector are among the highest in any economy, as it assembles the products of almost all industries. This upward shift of Australian construction sector probably results from the recent increase in the industrialisation of construction.

The input multiplier, which is the sum of all the row element of the Ghosh inverse matrix for a sector, reflects the sensitivity of industrial inputs to changes in the availability of primary inputs and the effect of one monetary unit change in value added by this sector on total input of all sectors (O'Connor and Henry 1975). This input multiplier indicator, which is calculated from Eq

(3b), represents the economic push effects of construction sectors. As indicated in Figure 7, the input multipliers of the construction sector in Japan fluctuates and the Australia' values decreased from 1970 to 1990.

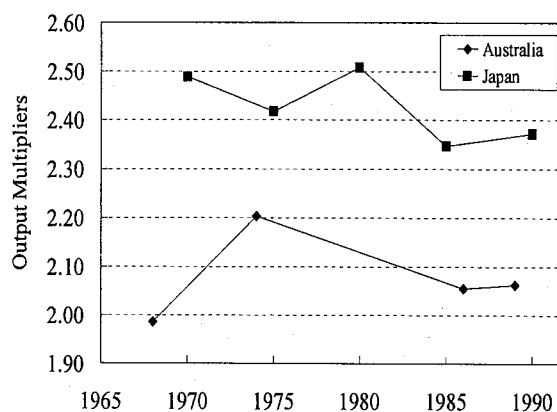


Figure 6: Output Multipliers

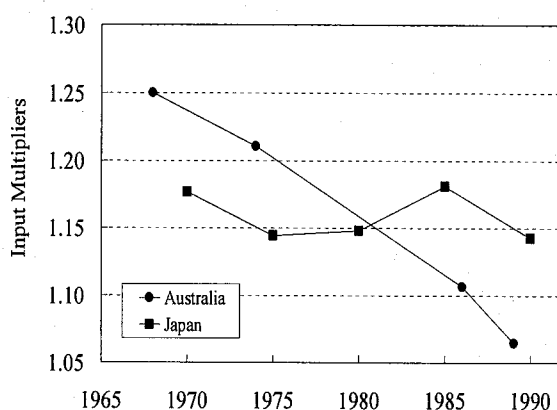


Figure 7: Input Multipliers

The construction sector produces intermediate goods and services only through its maintenance and repair construction sub-sector, most of these intermediate goods and services go to the real estate sub-sector of services. All other construction goods and services are included in various components of final demand by income accounting conventions.

5. PRODUCTIVITY INDICATORS OF CONSTRUCTION SECTORS

Based on the sectoral economic indicators, backward and forward linkage indicators and multiplier indicator, three productivity indicators are determined and discussed. Productivity can be expressed as the marginal relationship between the output generated from a system and the input used to create output. Productivity is widely used to measure the economic efficiency of production. In order to produce an overall measure of productivity of the construction sector, several productivity indicators are developed in this research, which are fully based on the above economic indicators generated from an input-output analysis. The above sectoral economic indicators, backward and forward linkage indicators, and multiplier indicators are used to formulate the intermediate productivity, sectoral productivity and aggregate productivity indicators, respectively.

5.1 Sectoral Productivity

The sectoral productivity, which is calculated from Eq (4a), is a measure of the gross influence of a sector on all industrial sectors. It indicates the sectoral final demand to value added ratio, which is also the same as the ratio between the contribution of a sector to GNP and its contribution to GNI. The value added consists of salaries, wages, capital consumption allowances, profits, net interest charges and taxes, and the final demand consists of the demands of households and governments and exports demands. This productivity indicator shows the capital employed efficiencies and the productive level of a sector in an economy. Figure 8 shows the construction productivities in Australia and Japan over the study period, which illustrates a relationship between the primary inputs utilised and the final outputs produced by the construction sectors.

This pattern shows that the productivity of Japan is obviously wavy, which is the result of the industry policies, net export and economic cycle (Grebler and Burns 1982). Moreover, the construction productivity of Japan is higher than that of Australia. A higher value means that the construction sector in Japan contributes more to the national product than to the national income. It also represents a higher level of industrialisation of the construction process in Japan compared to Australia. On the other hand, the pattern of Japan is relatively stable compared with that of Australia during the examining period, and the increasing magnitude in Australia is higher than in Japan. This reflects the different economic maturities between these two countries from the perspective of productivity because the wave of productivity does not tend to be broad in a mature economy.

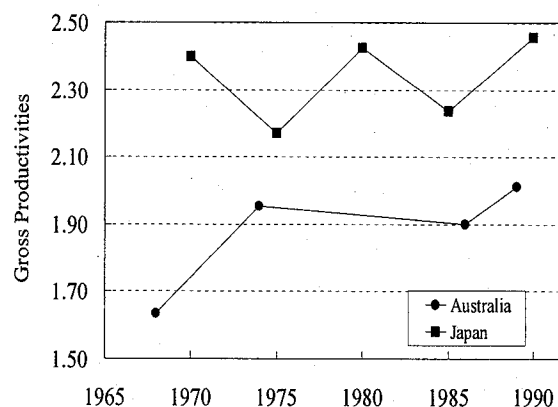


Figure 8: Sectoral Productivities

5.2 Intermediate Productivity

The intermediate productivity denotes the intermediate output to input ratio in the construction sector, which is also equal to the ratio between its forward linkage indicator to its backward linkage indicator according to Eq (4b). It represents the amount of product created by one unit of a group of factors of production over a stated period. Increases in productivity come from

increased efficiency on the part of inputs. Figure 9 shows the intermediate productivities for the two countries' construction sectors.

Both lines show a downward trend. Specially, the intermediate productivities of the Australia's construction sector decreased dramatically. This pattern can be explained by the intermediate input increasing slightly on the contrary the outputs to intermediate sectors decreasing noticeably during the study period, and the maintenance and repair construction sub- sector in Australia played a more important role in the national economics in the 1970s than 1980s. The decreasing outputs mainly due to the decline in the real estate, construction and transport and storage sectors. Presenting a striking contrast to Australia, the intermediate construction productivities of Japan shows a stable pattern over the exam period. The wave is very tiny during the study period except for the reference year 1985.

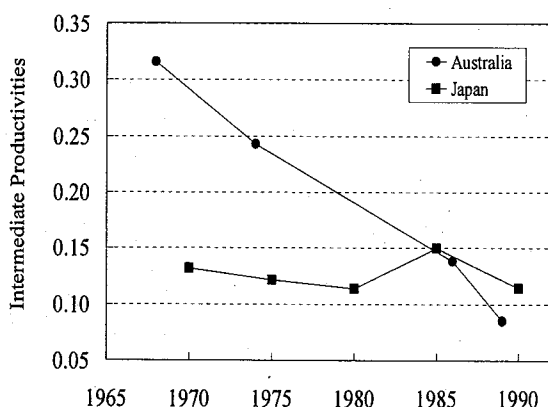


Figure 9: Intermediate Productivities

5.3 Aggregate Productivity

The aggregate productivity, which stems from Eq (4c), represents the ratio of the input multiplier multiplying final demand to the output multiplier multiplying value added of that industry. It measures the total efficiency of industry production resulting from all final demand sales

by the industry (West 1999). Figure 10 shows the aggregate productivities of construction sectors in Australia and Japan. The total final demand sales of Japan were higher than Australia's during the whole study period with the exception of the middle of 1970s. The low value of Japan in 1975 is derived from low intermediate outputs in that year and the multiplier amplified this influence. A higher indicator means the larger outputs such as reduced cost, improved service and increased volume or efficient inputs for instant materials, human resources and manage systems in the construction sector (SCRCSP 1997).

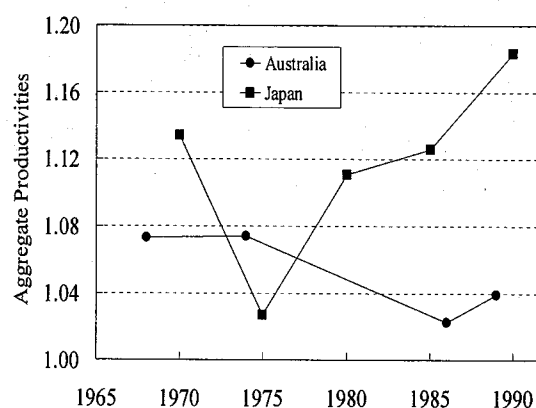


Figure 10: Aggregate Productivities

What is more, the aggregate productivities of Japan show a growing trend, whereas there is a decline trend in Australia. This "scissors" pattern is the consequences of the adoption of technological advances and the different industrial policy treatments. It is noted that this paper only focuses on the measuring of the aggregate productivities based on the input-output tables. Usually, the aggregate productivity data derived from survey and statistical methods can be found in national yearbooks. Our findings are not against these data.

6. CONCLUSIONS

This research takes advantage of the

input-output table to extend the economic indicator analysis and comparison and develops a perspective for determining the productivity of an industrial sector. The developed quantitative formulas are fully based on the available economic indicators from an input-output table. Using the newly published OECD input-output database, the historical analyses and comparisons are carried out to indicate the differences of productivities of the construction sectors in Australia and Japan. The findings can be concluded as follows:

The Japanese construction sector with a higher technology level contributed a bigger share than the Australian construction sector did over the study period. The forward linkage indicator values of the construction sector in Australia significantly tend to decline over these about twenty years. Whereas, the values in Japan did not show a clear changing track and fluctuated between 0.07 and 0.09 in these five years. The input multipliers of the construction sector in Japan fluctuated and the Australia's values decreased from 1970 to 1990.

The sectoral productivity of Japan was higher than that of Australia. A higher value means a higher level of industrialisation of the construction process in Japan compared to Australia over the study period. The intermediate productivities of the Australia's construction sector decreased dramatically. The intermediate productivities of Japan however showed a stable pattern over the exam period except for 1985. The aggregate productivities of Japan showed a growing trend, whereas there was a decline trend in Australia. This scissors pattern was the consequences of the adoption of technological advances and the different industrial policy treatments.

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