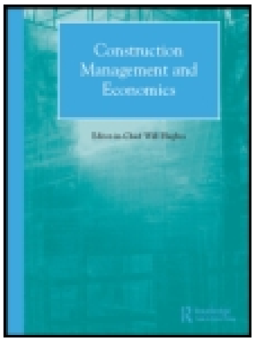

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Linkage measures of the construction sector using the hypothetical extraction method

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The hypothetical extraction method (HEM) is used to extract a sector hypothetically from an economic system and examine the influence of this extraction on other sectors in the economy. Linkage measures based on the HEM become increasingly prominent. However, little construction linkage research applies the HEM. Using the recently published Organisation for Economic Co-operation and Development input-output database at constant prices, this research applies the HEM to the construction sector in order to explore the role of this sector in national economies and the quantitative interdependence between the construction sector and the remaining sectors. The output differences before and after the hypothetical extraction reflect the linkages of the construction sector. Empirical results show a declining trend of the total, backward and forward linkages, which confirms the decreasing role of the construction sector with economic maturity over the examined period from a new angle. Analytical results reveal that the unique nature of the construction sector and multifold external factors are the main reasons for the linkage difference between countries. Moreover, hypothesis-testing results consider statistically that the extraction structures employed in this research are appropriate to analyse the linkages of the construction sector.

Keywords: Input-output analysis, hypothetical extraction method, construction sector, linkage

Introduction

Construction plays a significant role in any economy with a conspicuous contribution to economic growth, employment and income generation. More importantly, it provides the necessary public infrastructure and private physical structures for government, business, and domestic consumption (Polenske and Sivitanides, 1990). The relationships (linkages) between the construction sector and other sectors in the economy have attracted considerable research interest (e.g. Bon and Pietroforte, 1990; Pietroforte and Bon, 1999; Pietroforte *et al.*, 2000; Pietroforte and Gregori, 2003). Founded by Wassily Leontief in the late of 1930s, the input-output analysis focuses on how inter-sector trading influences the overall demand for labour and capital within an economy (Leontief, 1936). By displaying all flows of goods and services within an economy, the input-output technology has been considered a main tool to determine, define, measure and assess the linkages between sectors in the literature (Miller and Blair, 1985; Bon, 2000; Lean, 2001).

Theoretically, a sector's relationship with the rest of the economy through its direct and indirect intermediate purchases and sales are described as the sector's linkages (Miller and Lahr, 2001). The importance of the construction sector stems from its strong linkages with other sectors of the economy (Lean, 2001). Information on these linkages is essential to understanding the structure of an economy, which is in turn important in formulating industry policies (Cai and Leung, 2004). The direction and level of such linkages present the potential capacity of each sector to stimulate other sectors. The sectors with the highest linkages should be possible to stimulate a more rapid growth of production, income and employment than with alternative allocations of resources (Cella, 1984).

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Moreover, with the linkage measures, two different countries or regions can be compared and the methods may even be used to analyse technological and energy linkages (Pietroforte and Gregori, 2003; Su *et al.*, 2003). The linkages can be categorized into two groups according to the direction of interdependencies. One is the backward linkage, which identifies how a sector depends on others for their input supplies. Another is the forward linkage, which identifies how the sector distributes its outputs to the remaining economy. The backward and forward linkages have extensively been used for the analysis of interdependent relationships between economic sectors in order to determine appropriate development strategies.

In the context of input output tables, many linkage measure approaches can be found in the literature such as: power of dispersion, sensitivity of dispersion, coefficient of variation, the Sherman Morrison formula, eigenvalues, vertically integrated sectors, the hypothetical extraction method (HEM) and so on. In order to distinguish the HEM from these approaches, all other approaches except for the HEM are put into the conventional method category in this research. It has to be mentioned that not all linkage measure methods fall completely under one or other of the above. There is some overlap in this regard. For instance, Duarte *et al.* (2002) combined the vertically integrated sectors with the HEM and proposed a net linkage measure method. The conventional methods have received much criticism because they do not take into account all attributes that characterize the propulsive sectors in an interconnected economy (Hirschman, 1958).

The original idea of the HEM tries to extract a sector hypothetically from an economic system and examine the influence of this extraction on other sectors in the economy (Miller and Lahr, 2001). The HEM was mainly used to detect the key sectors. Linkage measures based on the HEM become increasingly influential (Dietzenbacher and Van Der Linden, 1997; Miller and Lahr, 2001). However, previous studies of the linkages between the construction sector and other sectors were mainly based on the conventional method. It is important, in order to gain a better comprehension of the specificities of the construction sector and its role in economic development, to examine these relationships from a new perspective.

Using the recently published Organisation for Economic Co-operation and Development (OECD) input-output database at constant prices, this research aims to apply the HEM to the construction sector in order to explore the role of this sector in national economies and the quantitative interdependence between the construction sector and other sectors from a new angle. This research comprises discussion of the underpinning literature, a description of the research method used, an analysis of the empirical results, and finally the conclusions of the research.

Underpinning literature

Hypothetical extraction method

Introduced by Paelinck *et al.* (1965), the HEM was further developed by Schultz (1976) and Cella (1984). Recent reviews can be found in Miller and Lahr (2001) and Cai and Leung (2004). Mathematically, the HEM was to quantify how much an economy's total output would decrease if a sector was extracted. Thus, by comparing the output levels for each of the remaining sectors before and after the hypothetical extraction, the impact of the extracted sector can be assessed. The difference between the output in the reduced case and in the original situation reflects the linkages between the extracted sector and all other sectors in the economy. The HEM can resolve two types of problems, one is the linkages between sectors can be measured properly, and the other is determination of which sector has the largest impact on the economy. Because it takes into account the relative magnitude of each sector's final demand in the economy and the relative effect of a sector on overall output, it is argued that the HEM is more suited to analyse the linkages than the conventional method (Andreosso-O'Callaghan and Yue, 2004).

In the literature, backward and forward linkages are widely accepted concepts for describing inter-sectoral relationships, yet how to measure them remains controversial, despite much research. Cella (1984) defined the 'total linkage', which built up an appropriate measure of 'the quantities of *n* goods directly and indirectly stimulated by the intermediate functions'. Moreover, Cella decomposed the total linkage into total backward and forward linkages. However, Cella's decomposition received a lot of criticism, which mainly focused on the definitions of forward and backward linkage components and the choice of the Leontief quantity model and Ghosh price model (Clements, 1990; Dietzenbacher and Van Der Linden, 1997; Cai and Leung, 2004). Following these arguments, a series of methods (transformations) were proposed, such as net linkage, absolute linkage, pure linkage and so on. Miller and Lahr (2001) reviewed all these transformations in light of the influence on output by using seven hypothetical extractions from the Leontief and Ghosh models and concluded that the total linkage derived from the HEM is an appropriate measure of an extracted sector's importance. Additionally, they suggested using the Leontief model to measure the backward linkage and the Ghosh model to measure the forward linkage. Their review and suggestions have been approved widely in the literature. In this research, Cella's method is used to measure the total linkage and another two extraction structures according to Miller and Lahr are adopted to explore the backward and forward linkages of the construction sector using the input-output tables of 36-sectors in eight OECD counties.

Linkage measures of the construction sector

Although linkage measures have been applied to many sectors in the economy, there is not much research that focuses on the construction sector using input-output technology (Lean, 2001). Some analysis using conventional methods mentioned above can be found in the literature. Ranko Bon and his colleague Roberto Pietroforte, who are the pioneers, first applied the linkage concept to the construction sector (Bon, 1988; Bon and Pietroforte, 1990). They considered that the input-output technology is an ideal tool, which provides a framework for studying both direct and indirect resource utilization in the construction sector. They also found that the technology can be used for studying four partially overlapping aspects of the construction sector: employment creation, construction linkage, construction productivity, and change in construction technology. Using the conventional linkage analysis methods, Bon and his colleagues discussed well the linkages of construction in Italy (Pietroforte and Bon, 1995, 1999), Japan (Bon and Pietroforte, 1990), Turkey (Bon *et al.*, 1999) and United States (Bon and Pietroforte, 1993). They concluded that the construction sector has low direct and total forward linkage because only the maintenance and repair construction sub-sector produces intermediate goods. They also observed that the construction sector has high direct and total backward linkages because the sector needs a large amount of national resources through direct purchases from other sectors. Especially, they considered that the backward linkage, which represents construction technology, is a rough indication of the strength of the construction sector's economic pull and the forward linkage is a rough indication of the strength of the construction sector's economic push. What is more, using the conventional method Polenske and Sivitanides (1990) analysed the backward linkages of the construction sector for 15 countries.

Recent studies on construction linkages using the conventional method can still be found. Pietroforte *et al.* (2000) discussed the role of the construction sector in the economy of Italy's North and South over a period of more than 30 years, and concluded that the North regions showed a relatively higher industrialization level of the construction sector based on its higher backward linkage. Pietroforte and Gregori (2003) first used the OECD input-output tables to conduct an input-output analysis of the construction sector in highly developed economies. They used conventional measures of linkages to determine the main source of induced output, which were created by the push and pull effects of the construction sector on the remaining economies in eight highly industrialized countries – namely Australia, Canada, Denmark, France, Germany, Netherlands, Japan and the United States. Su *et al.* (2003) examined the backward and forward linkages of the Taiwanese construction section using 12 input-output tables compiled between 1964 and 1999, and concluded that the value of backward linkages of the Taiwanese construction sector was approximately equal to that of the Japanese construction sector and the value of forward linkages increased significantly over time. Using the OECD input-output table, Liu and Song (2004) measured the real estate productivity using the conventional method. Song *et al.* (2004) compared the linkages between the construction and real estate sectors. Moreover, Liu *et al.* (2005) analysed the linkages of the real estate sector using the same set of tables. Even though studies on the linkages of the construction sector using the conventional methods have experienced a relatively strong revival recently, little construction linkage research uses the HEM to the best of our knowledge. Pietroforte and Gregori (1999) is an exemption – they re-decomposed Cella's total linkage into pure backward, forward and interconnection linkages for construction.

Methodology

This section introduces three different extraction structures of the HEM in order to explore the total, backward and forward linkages from a new angle.

Total linkage

In light of the basic idea of the HEM, it is assumed that the n-sector direct input coefficient matrix A has been partitioned into two groups: group one (sector 1) is a sector that is to be extracted from the economy (namely the construction sector in this research) and group two (sector 2) consists of all the remaining sectors of the economy. Then the Leontief model can be expressed as:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \times \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \tag{1}$$

where X_1 and X_2 denote the outputs of sector 1 and sector 2, and Y_1 and Y_2 denote the final demand of sector 1 and sector 2 respectively.

Now, sector 1 is hypothetically extracted from the economy. $\overline{X}_1$ and $\overline{X}_2$ denote the outputs of sector 1 and sector 2 after the extraction. Set $A_{12}=A_{21}=0$, Equation 1 can be expressed as:

$$\begin{bmatrix} \overline{X}_1 \\ \overline{X}_2 \end{bmatrix} = \begin{bmatrix} A_{11} & 0 \\ 0 & A_{22} \end{bmatrix} \times \begin{bmatrix} \overline{X}_1 \\ \overline{X}_2 \end{bmatrix} + \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \tag{2}$$

The difference between Equations 1 and 2 can be expressed as:

$$\begin{bmatrix} X_1\text{-}\overline{X}_1 \\ X_2\text{-}\overline{X}_2 \end{bmatrix} = \begin{bmatrix} \Pi\text{-}\alpha_{11} & \Pi A_{12}\alpha_{22} \\ \alpha_{22}A_{21}\Pi & \alpha_{22}A_{21}\Pi A_{12}\alpha_{22} \end{bmatrix} \times \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \tag{3}$$

where Π equals $(I\text{-}A_{11}\text{-}A_{12}\ \alpha_{22}A_{21})^{-1}$, I denotes the identity matrix and α_{22} equals $(I\text{-}A_{22})^{-1}$. Then, the total linkage (TL) can be expressed as:

$$\begin{aligned} TL = {} & [\lambda_1(\Pi\text{-}I) + \lambda_2\alpha_{22}A_{21}\Pi] \times Y_1 \\ & + [\lambda_1\Pi A_{12}\alpha_{22} + \lambda_2\alpha_{22}A_{21}\Pi A_{12}\alpha_{22}] \times Y_2 \end{aligned} \tag{4}$$

where symbols λ_1 and λ_2 are column summation vectors for sector 1 and sector 2 respectively. The TL has to be normalized before it is compared between countries. One way is to divide the TL by original outputs X and then multiply by 100%. This indicates the percentage decrease in economy-wide output because of the extraction (Miller and Lahr, 2001). Thus, the total linkage indicator can be obtained as:

$$\text{Total linkage indicator} = \frac{TL}{\lambda X} \times 100\% \tag{5}$$

where the symbol λ is a summation column vector.

Backward linkage

Similarly, assuming the sector 1 purchases import goods only to substitute completely for the local inputs, the backward linkage can be decided. From Eq. (1), let $A_{21}=0$, then, the backward linkage (BL) can be defined as:

$$\begin{aligned} BL = {} & [\lambda_1(\Pi\text{-}\alpha_{11}) + \lambda_2\alpha_{22}A_{21}\Pi] \times Y_1 + \\ & [\lambda_1(\Pi\text{-}\alpha_{11})A_{12}\alpha_{22} + \lambda_2\alpha_{22}A_{21}\Pi A_{12}\alpha_{22}] \times Y_2 \end{aligned} \tag{6}$$

where α_{11} equals to $(I\text{-}A_{11})^{-1}$ and the backward linkage indicator can be obtained as:

$$\text{Backward linkage indicator} = \frac{BL}{\lambda X} \times 100\% \tag{7}$$

Forward linkage

The measures of forward linkage are based on the extraction of the Ghosh model. The corresponding forward linkage can be obtained similarly. The basic Ghosh model can be partitioned and resolved as:

$$[X_1 \quad X_2] = [V_1 \quad V_2] \times \begin{bmatrix} \Gamma & \Gamma B_{12}\beta_{22} \\ \beta_{22}B_{21}\Gamma & \beta_{22}(I + B_{21}\Gamma B_{12}\beta_{22}) \end{bmatrix} \tag{8}$$

where B is the direct output matrix, V_1 and V_2 denote the value added of sector 1 and sector 2 respectively. γ equals $(I\text{-}B_{11}\text{-}B_{12}\beta_{22}B_{21})^{-1}$ and β_{22} equals $(I\text{-}B_{22})^{-1}$. It is assumed that sector 1 is hypothetically extracted, let $B_{12}=0$. Thus, Equation 8 can be rewritten as:

$$[\overline{X}_1 \quad \overline{X}_2] = [V_1 \quad V_2] \times \begin{bmatrix} \beta_{11} & 0 \\ \beta_{22}B_{21}\beta_{11} & \beta_{22} \end{bmatrix} \tag{9}$$

where β_{11} equals $(I\text{-}B_{11})^{-1}$.

Thus, the difference between Equations 8 and 9 can be calculated and the forward linkage (FL) can be obtained as:

$$\begin{aligned} FL = {} & V_1 \times [(\Gamma\text{-}\beta_{11})\lambda_1' + \Gamma B_{12}\beta_{22}\lambda_2'] + \\ & V_2 \times [\beta_{22}B_{21}(\Gamma\text{-}\beta_{11})\lambda_1' + \beta_{22}B_{21}\Gamma B_{12}\beta_{22}\lambda_2'] \end{aligned} \tag{10}$$

where λ_1' and λ_2' are row summation vectors for sector 1 and sector 2 respectively. The forward linkage indicator can be obtained as:

$$\text{Forward linkage indicator} = \frac{FL}{\lambda' X} \times 100\% \tag{11}$$

where λ' is a row summation vector.

Empirical results

The OECD input-output database, which is published by the Economic Analysis and Statistics Division of the OECD, provides appropriate multinational economic data (OECD, 1995). This is the most comprehensive database for comparing the construction sectors internationally so far (Pietroforte and Gregori, 2003; Liu *et al.*, 2005). Using the OECD input-output table, the HEM is applied to the construction sectors of Australia, Canada, Denmark, France, Germany, Japan, Netherlands and United States over 20 years. The construction sector has been extracted hypothetically from the economic system and the total, backward and forward linkages of the construction sector are calculated, analysed and compared in sequence.

Total linkage indicators of the construction sector

Total linkage indicator is one comprehensive measure of the construction sector's importance to the economy because all of construction's linkages to the rest of the economy are eliminated (the intra-sectoral flows of construction will remain). With the 'disappearance' of the construction sector, the remaining sectors in the economy would have to purchase from overseas and the construction sector's final demand would have to be satisfied by imports as well. The difference between the outputs before and after the extraction just reflects the importance of the construction sector. The total linkage indicators of the construction sector for the eight selected countries are generated from Equation 5 and illustrated in Figure 1, which shows two distinct groups of countries: Japan, Denmark and Canada with a relatively higher total linkage indicator and the remaining countries with lower ones. With a higher value, the construction sector seems to play a relatively important role in economic development in Japan, Denmark and Canada. The differences may be contributed by different industrial structures, relative prices, technology changes and government policies in different countries. For example, the proportion of civil engineering construction is very high in Canada, whereas Germany and France have a much lower value. The shares of residential construction are higher in Germany, Australia and France, whereas Canada and Denmark have a lower value.

In order to reflect the entire trend and average level, the arithmetic means of the total linkage indicators are calculated and depicted in Figure 1. It can be observed that the values tend to decline over the examined period. In the late 1980s, the pace of decline is reversed in most of the countries. The reason may be due to the increase in the price of construction materials in these countries (Pietroforte and Gregori, 2003). The declined pattern in substance supports the argument of Bon and Pietroforte (1990), who claimed that the role of the construction sector is diminishing with economic maturity. However, it has to be noted that the volumes of construction are underestimated because construction is a very pervasive activity undertaken by almost every residential owner and business entity, and these private construction activities are only partially captured by official statistics (Carassus, 2004).

A vertical comparison of the total linkage indicator for particular countries is also needed. According to Equation 5, the total linkages of 36 sectors are calculated and ranked for all eight countries, and the ranking of the construction sector of these countries is reported in Table 1. Except for Germany and Netherlands, all values of the total linkage of the construction sector are ranked as the top five. Interestingly, the values ranked Japan first over the whole examined period. Moreover, a trend of slight decline of the ranks is apparent, except for Canada, all other ranks were decreasing or kept constant between the initial and final stages of the examined period. These declining ranks provide further evidence for the argument of Bon and Pietroforte.

Table 1 Ranks of the construction total linkage indicator

	Early-1970s	Mid/late-1970s	Early-1980s	Mid-1980s	Late-1980s
Australia	2	2	N/A	3	3
Canada	3	3	2	3	2
Denmark	3	2	3	3	3
France	2	3	4	5	3
Germany	N/A	6	N/A	6	7
Japan	1	1	1	1	1
Netherlands	3	6	7	7	N/A
USA	1	1	1	3	3

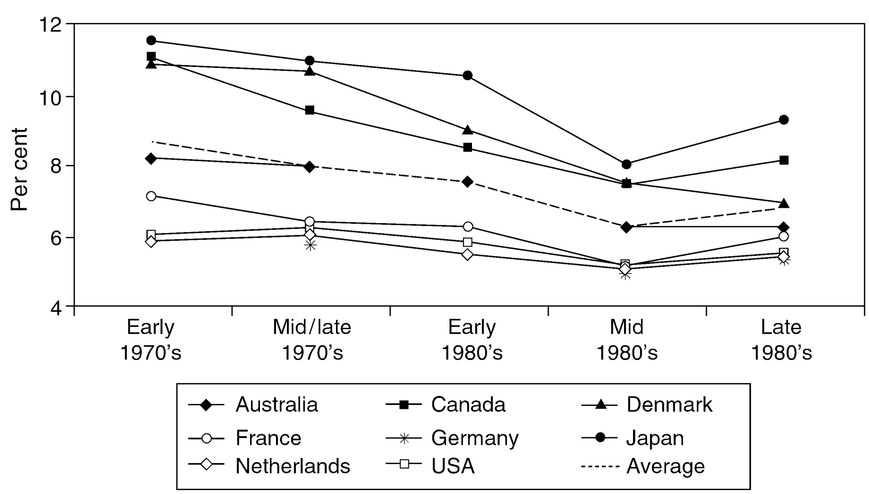

Figure 1 Total linkage indicators

Backward linkage indicators of the construction sector

Assuming that all local product inputs of the construction sector are extracted and all inputs will depend on imports, the backward linkage of a sector reflects this sector's dependence on local inputs that are produced within the production process of the economy. A strong backward linkage suggests a weak sectoral independence. On the other hand, a high value represents a strong economic pull of the construction sector to the remaining sectors. The backward linkage induces growth through the process of derived demand because the remaining sectors would have to face the losses without the purchase of the construction sector. What is more, the backward linkage indicator is a measure of the degree of the industrialization of the construction production process and the national technology difference in terms of intermediate and value added inputs composition (Pietroforte and Gregori, 2003), because it is generally agreed that input-output tables reflect a general equilibrium model of the economy where inputs are allocated according to technological availability.

The backward linkage indicators of the construction sector for the eight selected countries are calculated from Equation 7 and presented in Figure 2. The value of the backward linkage indicators are scattered between 4% and 11% over the examined period. Similar to the total linkage indicators, the backward linkage indicators show two distinct groups of countries: Japan, Canada and Denmark, with a relatively higher backward linkage indicator and the remaining countries with lower ones. With a higher value, the Japanese, Canadian and Danish construction sectors show relatively weak economic independence, strong pull effects to the remaining sectors of the economy and a higher technology level. The average values of the backward linkage indicators are plotted in Figure 2. It can be observed that the values tend to decline over the examined period. It seems that the decline in the backward linkage is the main reason of the decline in the total linkage.

Like the total linkages, the backward linkage ranks of the construction sector are listed in Table 2. Except for Germany in late-980s, and Netherlands in early-1980s and mid-1980s, all values of the backward linkage of the construction sector are ranked in the top two. Particularly, the values are ranked first in Japan and USA over the entire examined period. Except for the Netherlands, most of ranks keep constant or vary slightly between the initial and final stages of the examined period compared with the total linkages.

Table 2 Ranks of the construction backward linkage indicator

	Early-1970s	Mid/late-1970s	Early-1980s	Mid-1980s	Late-1980s
Australia	2	2	N/A	1	1
Canada	2	2	2	2	2
Denmark	2	2	2	2	2
France	1	1	1	2	1
Germany	N/A	2	N/A	3	4
Japan	1	1	1	1	1
Netherlands	2	2	5	5	N/A
USA	1	1	1	1	1

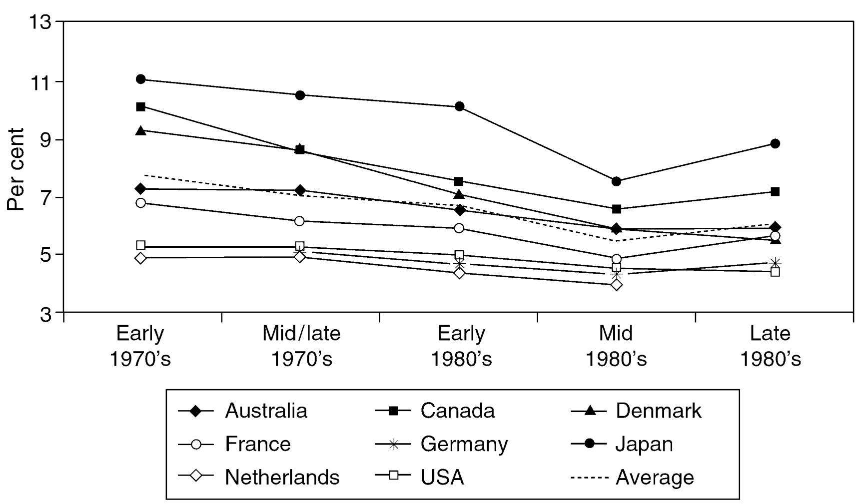

Figure 2 Backward linkage indicators

Forward linkage indicators of the construction sector

The forward linkage of a sector reflects the dependence of the remaining sectors in the economy on this sector's supplies that are produced within the production process. Assuming that the construction sector just sells for export, except for deliveries to itself, the difference between the outputs in the reduced case and in the original situation reflects the economic losses of the remaining sectors of the economy without the supply of the local construction sector. The forward linkage indicators of the construction sector for the eight selected countries are calculated from Equation (11) and depicted in Figure 3. The value of forward linkage indicators are stabilizing at a low value between 0.3% and 2.6%, and their time profiles show relative stability during the observed period compared with the backward linkage indicators. A weak forward linkage shows a strong sectoral independence and a weak economic push of the construction sector. The construction sector of Denmark, Netherlands, Canada and USA show a stronger economic push and a weak sectoral independence with a higher forward indicator, while the others have a weaker one. The arithmetic means of the forward linkage indicators are plotted in Figure 3. It can be observed that the values tend to decline slightly over the examined period and the trend is flatter than those of the total and backward linkages.

The forward linkage's ranks of the construction sector for these countries are presented in Table 3. Three significant differences can be observed among the ranks of the forward linkage and those of the total and backward linkages. First, except for Denmark, Netherlands and USA in late-1980s, all ranking values of the forward linkage of the construction sector are below number 10. Second, a momentous decline in the ranks can be observed except for Canada and USA between the initial and final stages of the examined period. Third, the ranking differences among these countries are noticeable. The ranks of Netherlands and Denmark are obviously higher than those of other countries.

In fact, in the context of the input-output table, the intermediate demand of the construction sector contains only the maintenance and repair flows to the remaining sectors and most of the production of the construction sector goes to the final demand, which represents new construction. This explains why the forward linkage of the construction sector has a lower value and a lower rank. However, it should be noted that maintenance and repair construction is not as well covered as new construction by official statistics due to do-it-yourself activities and the black economy (Pietroforte and Gregori, 2003).

Table 3 Ranks of the construction forward linkage indicator

	Early-1970s	Mid/late-1970s	Early-1980s	Mid-1980s	Late-1980s
Australia	12	15	N/A	22	25
Canada	13	14	9	9	12
Denmark	9	7	9	10	10
France	18	18	20	21	21
Germany	N/A	16	N/A	17	17
Japan	21	21	21	20	22
Netherlands	6	8	8	8	N/A
USA	12	10	12	14	8

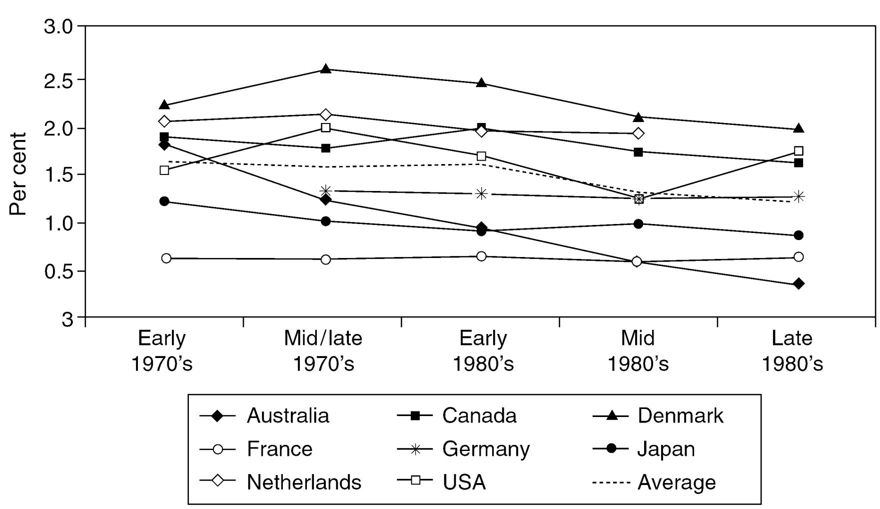

Figure 3 Forward linkage indicators

Discussion

Some issues raised from the extraction should be discussed further. Firstly, since the intra-sectoral flow has been kept in the linkage measures, the magnitude of construction internal linkage effect should be investigated. From Equation 2, let $A_{11}=0$, a 'complete extraction' can be performed. Comparing the complete extraction with the total linkage above, the direct differences are reported in Table 4. To some extent, the direct differences reflect the internal linkage effect of construction, which represents the sector's self-supply. As can be seen in Table 4, the internal effect of construction is very small. Except for Netherlands and Canada, all values are less than 0.1 percent. The magnitude of this internal linkage effect depends in part on the level of aggregation in the input-output model (Miller and Lahr, 2001). It would seem that construction has a small aggregation level in the input-output model. In other words, the internal effect of construction has a limited influence on the total linkage.

Secondly, the output differences between the actual outputs and the hypothetical outputs should be discussed. The construction output differences between the hypothetical outputs and the actual outputs are calculated. The ratios of these output differences to the actual outputs are reported in Table 5. It can be seen that Japan, Denmark and Canada have a higher ratio compared with the remaining countries. Compared with the actual outputs, this pattern means the construction sectors of Japan, Denmark and Canada have a higher hypothetical output, which means a higher potential production capacity. Hence this pattern also supports the above argument that the construction sector seems to play a relatively important role in economic development in Japan, Denmark, and Canada.

Moreover, the total, backward and forward linkage differences amongst countries are worthy to be investigated statistically and further discussed. Firstly, a descriptive statistic is conducted to enumerate the differences over the examined period. Table 6 reports the sample numbers, mean, standard deviations, minimum, maximum values and mean ranks of the total, backward and forward linkages respectively. Obviously, some discrepancies can be observed in different study periods.

Polenske and Sivitanides (1990) summarized that the difference in backward linkages among countries and over time may be attributable to variations in three factors: product mix, relative prices, and technologies. However, in fact, some other factors also should be mentioned here including government policies, cultural differences and managerial levels. Firstly, government policies include fiscal and financial policies, for example, the government can initiate large infrastructure projects in order to induce economic development and the government can reduce financial building support and defer civil-engineering projects to prevent overheating in the national economy. These policy

Table 4 The internal linkage effect of construction

	Early-1970s	Mid/late-1970s	Early-1980s	Mid-1980s	Late-1980s	Average
Australia	0.00096	0.00022	N/A	0.00006	0.00007	0.00096
Canada	0.00080	0.00104	0.00279	0.00191	0.00139	0.00080
Denmark	0.00010	0.00006	0.00005	0.00037	0.00017	0.00010
France	0.00004	0.00003	0.00003	0.00002	0.00002	0.00004
Germany	N/A	0.00071	N/A	0.00046	0.00050	N/A
Japan	0.00010	0.00002	0.00007	0.00010	0.00024	0.00010
Netherlands	0.00943	0.00898	0.00859	0.00864	N/A	0.00943
USA	0.00001	0.00004	0.00004	0.00006	0.00005	0.00001

Table 5 The ratios of the construction output differences to the actual outputs

	Early-1970s	Mid/late-1970s	Early-1980s	Mid-1980s	Late-1980s	Average
Australia	0.08	0.31	N/A	0.12	0.10	0.15
Canada	0.45	0.28	0.19	0.21	0.26	0.28
Denmark	0.43	0.73	0.67	0.62	0.57	0.60
France	0.12	0.12	0.14	0.09	0.21	0.14
Germany	N/A	0.07	N/A	0.05	0.09	0.07
Japan	0.56	0.47	0.56	0.41	0.42	0.49
Netherlands	0.03	0.16	0.16	0.15	N/A	0.12
USA	0.10	0.28	0.22	0.16	0.24	0.20

Table 6 Descriptive statistic of the linkages

Period		N	Mean	Std. deviation	Minimum	Maximum	Mean rank
Early-1970s	Total	7	0.0871	0.0248	0.0589	0.1161	1
	Backward	7	0.0782	0.0238	0.0491	0.1104	2
	Forward	7	0.0162	0.0056	0.0061	0.0225	3
Mid/late-1970s	Total	8	0.0797	0.0215	0.0582	0.1098	1
	Backward	8	0.0706	0.0205	0.0490	0.1050	2
	Forward	8	0.0158	0.0066	0.0060	0.0259	3
Early-1980s	Total	6	0.0760	0.0203	0.0547	0.1051	1
	Backward	6	0.0669	0.0204	0.0445	0.1009	2
	Forward	6	0.0161	0.0069	0.0065	0.0245	3
Mid-1980s	Total	8	0.0622	0.0128	0.0504	0.0802	1
	Backward	8	0.0547	0.0124	0.0399	0.0757	2
	Forward	8	0.0130	0.0058	0.0059	0.0211	3
Late-1980s	Total	7	0.0680	0.0145	0.0544	0.0930	1
	Backward	7	0.0609	0.0153	0.0451	0.0888	2
	Forward	7	0.0122	0.0061	0.0036	0.0198	3

differences will impact directly on the backward linkage. Secondly, cultural differences also can influence the strength of the backward linkage. For example, in some countries, businesses prefer investing in residential buildings rather than in the highways and utilities. Lastly, managerial levels will affect the extent of the construction sector tied to other sectors and consequently it has an effect on the backward linkage of the construction sector.

The rank differences and decreasing trend in forward linkages among countries may be attributable to three factors: institutional regulations, the management of existing construction and the weighting of the construction sector. The first factor is the differences of the institutional regulations among countries. The differences of the central government, industrial and professional organization regulations among countries may induce directly the productivity differences of the construction sector and then have an effect on the forward linkages of this sector. The second factor is the difference in the management of existing construction. The optimization and renewal of the stock of existing construction has become a central issue of construction activity in developed countries (Carassus, 2004). The role of maintenance and repair construction differs by countries. By and large, the volume of the maintenance and repair construction grows with economic maturity and the decreasing land capability. The third factor is that the share of the construction's value added in GDP is different among countries. The weighting of value added also has an effect on the value of the forward linkage since the share of value added of the construction sector decreases with economic maturity.

Furthermore, in order to investigate the stability and consistency of three extraction structures of the HEM implemented in the construction sector, the Kendall's coefficient of concordance (W) has been tested to determine if there are any agreements among the total, backward and forward indicators over the examined period. The three indicators are ranked respectively and the Kendall's W is worked out for the three linkages. Table 7 presents the Kendall's W of the total, backward and forward indicators. As expected, comparison results suggest that there are perfect agreements (Kendall's W=1.00) over the five study periods for the three indicators. The results mean that the three extraction structures seem to be appropriate to analysis the linkages of the construction sector.

Table 7 Kendall's Coefficient of Concordance

	N	Kendall's W[a]	Chi-Square	df	Asymp. Sig.
Early-1970s	7	1.00	14	2	0.001
Mid/late-1970s	8	1.00	16	2	0.000
Early-1980s	6	1.00	12	2	0.002
Mid-1980s	8	1.00	16	2	0.000
Late-1980s	7	1.00	14	2	0.001

[a]Kendall's Coefficient of Concordance

Conclusions

Using the OECD input-output database at constant prices, this research has applied the HEM to the construction sector in order to explore the role of the sector in national economies and the quantitative interdependence between the construction sector and other sectors from a new angle. By comparing the output levels for each of the remaining sectors before and after the hypothetical extraction, the difference between the output in the reduced case and in the original situation reflects the linkages amongst the construction sector and all other sectors in the economy. As expected, the total, backward and forward linkages show clearly a decreasing trend, which confirms the diminishing role of the construction sector with economic maturity over the examined period. Moreover, the decline in the total linkage is mainly contributed by the decline in the backward linkage.

Meanwhile, empirical results show the linkage differences among countries. The Japanese, Danish and Canadian construction sectors seem to play a relatively important role in economic development with a relatively higher total linkage indicator and the remaining countries have lower ones. With a higher value of the backward linkage, the Japanese, Canadian and Danish construction sectors also show relatively weak economic independence, strong pull effects to the remaining sector of the economy and a higher technology level. The values of forward linkage indicators are stabilizing at a low value between 0.3% and 2.6%, and their time profiles show relative stability during the observed period. The construction sectors of Denmark, Netherlands, Canada and USA show a stronger economic push and a weak sectoral independence with a higher forward indicator, while the others have a weaker one. In addition to the reasons that have been mentioned by previous research, it is concluded that government policies, cultural differences and managerial levels may also affect the backward linkage and the forward linkage may be influenced by institutional regulations, the management of existing construction, and the weighting of the construction sector. Moreover, hypothesis testing results show that the extraction structures employed in this research are appropriate to analyse the linkages of the construction sector.

However, it has to be mentioned that pure input-output based linkage has short-comings for identifying core relations in economic systems. Some external data sources, such as research and development data, patent data, fund and knowledge flows and so on, have been used with the input-output table in recent research. Further studies will focus on these fields and the HEM could be even more powerful to measure the linkages of the construction sector in the future.

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