Quantifying the Linkages and Leakages of Construction Activities in an Open Economy Using Multiregional Input–Output Analysis

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Abstract: This study proposes an analytical framework to evaluate the economic influence and leakage of the construction sector in a small and open economy, using Hong Kong as a case study. Input–output analysis (IOA) is used to capture the domestic intersectoral linkages, and multiregional IOA is used to measure the leakages resulting from international trade. In the absence of Hong Kong official input–output tables (IOTs), five IOTs during 1995–2013 and three multiregional IOTs from 2004, 2007, and 2011 are compiled using the Global Trade Analysis Project (GTAP) database in conjunction with official statistics. Comparisons with other economies are included to disclose the relative economic influences of Hong Kong's construction sector. The results reveal the declining economic importance of Hong Kong's construction sector in stimulating economic growth, along with increased leakage to the manufacturing sectors abroad. The domestic backward linkage dropped from 1.74 in 1995 to 1.55 in 2013 per unit of final demand. In 2011, 40.55% of the economic contribution leaked out through international trade. The outcomes provide a rational basis with which to inform the decision making of the Hong Kong government in infrastructure planning, resource utilization, and benefit optimization. An import substitution policy is recommended to ease foreign dependence through local production of construction products. **DOI: 10.1061/(ASCE)ME.1943-5479.0000653.**

Author keywords: Construction sector; Import-dependent economy; Linkage; Leakage; Input–output analysis.

Introduction

The vital role of construction activities in economic growth is well recognized (Hillebrandt 2000; Giang and Pheng 2011; Barber and El-Adaway 2015; Ho 2016; Lam and Oshodi 2016). A positive correlation between construction output and the level of economic output has been confirmed (Turin 1973; Hosein and Lewis 2005; Chiang et al. 2015) because capital formation is the crucial driver of economic growth in classical growth theories (Boskin and Lau 1991; Lopes et al. 2002). There are numerous influencing factors that may affect the economic impacts of construction activities on the economy: industrialization (Bon and Pietroforte 1990; Ilhan and Yaman 2011), economy scale (Dietzenbacher 2002; Myers 2013), technology and labor productivity (Bon 2000; Sposi 2015), and domestic resource usage and imports (Polenske and Sivitanides 1990). Many of these factors are interrelated, and the resultant impacts caused by these variables frequently appear as aggregate outcomes. The aggregated sectoral changes can be observed from input–output analysis (IOA), which depicts intersectoral flows among sectors in an economy. The sectoral interdependence is assessed and presented as linkage indicators.

The importance of the construction sector in stimulating economic growth has been highlighted in numerous studies based on IOA. Sectors with widespread activities throughout the economy tend to have a greater magnitude of linkages (Dietzenbacher 2002; Reis and Rua 2009), which is proven to be the case for the construction sector (Polenske and Sivitanides 1990; Gundes 2011). The construction sector is also characterized by its strong demand pull effect and relatively weak supply push effect, as revealed by backward and forward linkage indicators (Polenske and Sivitanides 1990; Ilhan and Yaman 2011; Gregori and Pietroforte 2015). This demonstrates that construction activities can spur economic activities through intermediate input demand from various supplying sectors.

A conclusive statement that the economic contribution of the construction sector in advanced economies has declined over time because of deindustrialization and the declining contribution of the manufacturing sector was pointed out in several studies using IOA. Bon and Pietroforte (1990) and Pietroforte and Gregori (2003) reported that the economic influence of the construction and manufacturing sectors declines once the economy enters the stage of deindustrialization in some advanced economies, including Australia, Japan, and the United States. Pietroforte et al. (2009) suggested that the declining economic importance of the US construction sector from 1947 to 2002 was strongly affected by the shrinking intermediate inputs. The decreasing contribution of manufacturing inputs was partially offset by the steady growth of service inputs. Ilhan and Yaman (2011) documented similar observations in

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Note. This manuscript was submitted on December 19, 2017; approved on October 10, 2018; published online on November 12, 2018. Discussion period open until April 12, 2019; separate discussions must be submitted for individual papers. This paper is part of the ***Journal of Management in Engineering***, © ASCE, ISSN 0742-597X.

Ireland, the Netherlands, and Sweden from 1998 to 2002. The shift of intermediate inputs has been attributed to the level of industrialization, technology transformation, price fluctuation, and labor productivity (Bon 2000; Pietroforte et al. 2009; Sposi 2015).

Small countries with limited domestic market size face stronger incentives to remain open to sustain the level of economic activity and productivity (Alesina and Wacziarg 1998; Ram 2009). Some studies use population, land area, or gross domestic product (GDP) as the indicators for country (economy) size (Rodríguez and Rodrik 2000; Ram 2009), whereas others argue that an economy is classified as small in the sense that it has no discernable influence on the world output, price level, and interest rate (Clarida et al. 2001; Dib 2011). Also, the meaning and measure of trade openness are interpreted differently in empirical studies (Rodríguez and Rodrik 2000; Yanikkaya 2003). The share of trade volume (imports plus exports) in the GDP is the most basic measure, whereas others claim that trade barriers, trade orientation, or the exchange rate should be used to represent the openness measure (Yanikkaya 2003).

Because an open economy is more subjective to external shocks and its macroeconomic policy is largely powerless to influence the use of imported inputs, IOA becomes indispensable for rational policy formation to make optimal use of resources (Baumol and Wolff 1994). Based on the IOA of six European Union (EU) economies in 1985, Dietzenbacher (2002) noted that small economies (Belgium, Denmark, and the Netherlands) appear to have smaller economic impacts than large diversified economies (Germany, France, and Italy), indicating that the economic activities of small economies generally depend more on imports and exports, with larger leakage effects. The construction sector is no exception. In this article, leakage is defined as the loss of economic output with the use of imported goods and services (Guo and Planting 2000).

The results from previous studies quantifying the construction sectoral performance in small open economies do not comply fully with the results from large economies. For the production structure, increasing dependency on the service sectors has been reported for North Cyprus (Mehmet and Yorucu 2008) and Sri Lanka (Rameezdeen and Ramachandra 2008). As for the linkage, some studies have claimed that there is no difference in the construction sectoral performance among Denmark, the Netherlands (Pietroforte and Gregori 2003), and other large economies, whereas some have stated that small economies tend to have lower total backward linkages, such as Finland (Bon and Pietroforte 1990) and Sri Lanka (Rameezdeen and Ramachandra 2008). Previous studies on Hong Kong have revealed that a 1-unit increase in construction final demand led to 1.20–1.31 units of output in the years 1962, 1973, and 1997/1998 (Hsia et al. 1975; Sung 1979; Voon and Ho 2001). Among all sectors, the backward linkages of Hong Kong's construction sector are less than those from the mining and agricultural sectors but greater than those of the labor-intensive sectors (Voon and Ho 2001). These observations are different from other studies that demonstrated greater backward linkages of the construction sector in other small open economies. Bon and Pietroforte (1990) stated that the linkage values for Finland ranged from 1.70 to 1.9 from 1959 to 1985. Similar findings were reported by Bon and Yashiro (1996), Pietroforte and Gregori (2003), and Ilhan and Yaman (2011), with linkage values larger than 2.0 in Denmark, Finland, Hungary, the Netherlands, Turkey, and Sweden prior to 2002.

The distinctive IOA outcomes of Hong Kong may reflect the following presumptions. First, the economic structure of the evaluated economies is different in nature. Hong Kong is a small economy (regarding population and land area and as a price-taker) that adopts outward-oriented policies (Rao and Singh 2010), with trade volume exceeding 340% of the GDP in 2014 (Census and Statistics Dept. 2016a). Its high dependence on external trade led to a skewed economic structure in which the dominating service sectors comprised over 92.7% of the GDP, and the share of the manufacturing sector fell to 1.3% in 2014 (Census and Statistics Dept. 2016a). The extensive use of imported goods combined with skewed economic structure alters the interdependence of the construction sector through the production process and trading behavior. Despite extensive research on the IOA of the construction sector in numerous developed and developing countries, to the best of the knowledge of the authors, few studies have focused solely on small developed economies, and none has addressed the leakage issue in detail. Second, the absence of continuing IOA hampers the study of the evolving contribution of Hong Kong's construction sector over time because the interdependence between the construction sector and other sectors is not static (Bon 1988). The unavailability of input–output tables (IOTs) as official statistics poses a challenge to the investigation, and the latest IOT of Hong Kong for the fiscal year 1997/1998 does not cover current conditions.

To better understand the influence of Hong Kong's construction sector in stimulating economic growth, this study involved analyses performed in three phases: (1) investigating the linkages of the construction sector by compiling a series of IOTs for the years 1995, 2000, 2005, 2010, and 2013; (2) identifying the leakages of construction activities by compiling multiregional IOTs (MRIOTs) for the years 2004, 2007, and 2011; and (3) comparing outcomes with other economies. First, measures of linkage and leakage were used to quantify interdependence and trade effects for Hong Kong's construction sector and hence to investigate its changing economic importance from 1995 to 2013. The relationship between domestic linkages and leakages was considered from a global perspective, and then the assessments on the sectoral performance regarding linkages and leakages throughout time in Hong Kong and other economies were reviewed. Also, the potential causes for the changes were explored. These phases were expected to provide a more comprehensive view of the sector-specific and overall economic benefits proceeding from construction activities in Hong Kong. The coupling results with other compared economies were used to draw policy-relevant observations for Hong Kong and for other small open economies that have been undergoing deindustrialization.

The article proceeds as follows: The first section outlines the analytical framework, data sources in constructing Hong Kong IOTs and MRIOTs, and the commonly used measures. The resulting empirical results are presented in the following section. Next, the construction linkages and leakages of Hong Kong and other advanced economies are summarized and compared. The shift of production structure, sectoral interdependence, and import dependence over time are discussed with explanations. The article concludes with future research suggestions.

Materials and Methods

In this study, a series of IOTs from 1995 to 2013 and a series of MRIOTs from 2004 to 2011 for Hong Kong were constructed to analyze the ability of the construction sector to stimulate economic growth in a small and import-dependent economy. Various data sets were used to compile the Hong Kong IOTs to ensure accuracy and consistency. Many of the data sources are listed in Table S1 of the Supplemental Data.

Considering the availability of statistics and the service-dominated economic structure, Hong Kong IOTs have been divided into 10 sectors: (1) agriculture, (2) manufacturing, (3) utilities, (4) construction, (5) wholesale and retail trade, (6) transport and storage, (7) information and communication, (8) financing and insurance, (9) professional and support activities, and (10) other services. Comparisons in sectoral classification between the Hong Kong Global Trade Analysis Project (GTAP) database and other economies are summarized in Table S2 of the Supplemental Data.

For the compilation of intersectoral transaction tables in the years 1995, 2000, 2005, 2010, and 2013, the intersectoral flow coefficients were extracted from the GTAP database for the base years 1997, 2001, 2004, 2007, and 2011. The GTAP database comprises balanced, harmonized data (Narayanan and Walmsley 2008; Peters et al. 2011) and inclusive sets of accounts outlining the annual flows of goods and services with regional and sectoral detail for 140 regions (Aguiar et al. 2016). Nonetheless, the base years of the GTAP are different from the proposed Hong Kong IOTs. Proportional adjustment and standard RAS methods were used for updating the transaction tables by reconciling and balancing the columns and rows. The basic principles and procedures applied are discussed by Parikh (1979) and Toh (1998).

Other input data, such as intermediate consumption, value-added, final demand, imports, and exports, were extracted from official statistics. Parts of the applied secondary data were regrouped or separated into the appropriate classified sectors. The published statistics for imports and exports are incomplete, so estimations and assumptions were applied to fill the gaps by referring to the composition of Singapore IOTs because Singapore's economic structure and scale are similar to those of Hong Kong (Young 1992; Zimring et al. 2010). For the IOT for the year 2010, the data of 10 principal commodities of merchandise trade (Census and Statistics Dept. 2016d) and merchandise trade classified by end-use category (Census and Statistics Dept. 2016b) were used to allocate the imported and exported values in agriculture, manufacturing, and utilities. Data on international trade in services (Census and Statistics Dept. 2016c) that are provided in numerous subgroups were relocated to the proposed sectors. A comparison between Singapore and Hong Kong trade values in ratios was then conducted to identify the missing gaps. As for the imported commodities, the remaining values were redistributed to construction, professional and support activities, and other services.

Based on the transaction tables, three matrixes were constructed: a technical coefficient matrix ($\mathbf{A}$), the Leontief matrix $(\mathbf{I}-\mathbf{A})$, and the Leontief inverse matrix $(\mathbf{I}-\mathbf{A})^{-1}$. For an IOT with n sectors, the input coefficient (a_{ij}) is expressed as the ratio of the intermediate deliveries (Z_{ij}) from Sector i to Sector j over the total input of the latter sector (X_j). The input coefficient can be written as

$$a_{ij} = Z_{ij}(X_j)^{-1} \tag{1}$$

$$Z_{ij} = a_{ij}X_j \tag{2}$$

The estimated input coefficient for each sector is used to construct the technical coefficient matrix ($\mathbf{A}$), shown as $\mathbf{A} = [a_{ij}]$ under the assumption that the structure of production and the prices of inputs are fixed. When sectoral linkages are measured by total intermediate transactions, regardless of whether they come from domestic or international producers, it will lead to the overestimation of the linkage effect (Dietzenbacher et al. 2005; Reis and Rua 2009). In this study, imports were determined exogenously to separate the imported and domestic supplies and demands. Matrix $(\mathbf{A^d})$ is used to represent the domestic coefficients matrix excluding imports. Imported inputs are assigned as a new industry category aside from matrix $(\mathbf{A^d})$, and the final demand entries of imports are computed as a negative value in final demand; thus, the domestic final demand ($\mathbf{Y^d}$) is delivered. The supply–demand balance equation used to represent the transaction flows of an economy in matrix notation is given as

$$\mathbf{X} = \mathbf{A^d}\mathbf{X} + \mathbf{Y^d} \tag{3}$$

where $\mathbf{X}$ = vector of domestic gross output; and $(\mathbf{A^d}\mathbf{X})$ and $\mathbf{Y^d}$ = vectors of domestic intermediate demand and final demand, respectively. The vector of output $\mathbf{X}$ can be solved by

$$(\mathbf{I}-\mathbf{A^d})\mathbf{X} = \mathbf{Y^d}$$

$$\mathbf{X} = (\mathbf{I}-\mathbf{A^d})^{-1}\mathbf{Y^d} \tag{4}$$

where $\mathbf{I}$ = identity matrix; and $(\mathbf{I}-\mathbf{A^d})^{-1}$ = matrix of interdependence coefficients.

Through these processes, the Leontief matrix $(\mathbf{I}-\mathbf{A^d})$ and inverse matrix $(\mathbf{I}-\mathbf{A^d})^{-1}$ of Hong Kong were completed for later analysis. The concepts and methods used in the compilation of IOTs are given in detail by Miller and Blair (2009). The Leontief inverse matrix of Hong Kong for 2013 is shown as an example in Table S3 of the Supplemental Data.

Measures of Hong Kong IOA

Common measures derived from IOTs include (1) direct backward and forward linkages, (2) domestic backward and forward linkages, (3) normalized measures of backward and forward linkage, and (4) coefficient of variation (Polenske and Sivitanides 1990; Reis and Rua 2009). In this article, these indicators are used to examine demand and supply trends of Hong Kong's construction sector. Import and value-added multipliers are also included to illustrate the leakage and value-added generated in local industries induced by the construction activities. The equations and principles for these indicators are presented in Table S4 of the Supplemental Data.

From the demand side, the direct backward linkage is used to indicate the production structure by revealing the intermediate inputs and value-added composition, whereas the domestic backward linkage (output multiplier) illustrates the economy-wide effects of a given increase in the final demand of a sector. The configuration of backward linkage (interdependence coefficient) for a sector reveals its dependencies on other sectors. From the supply-side perspective, the direct forward linkage highlights the share of the total output of a sector accounted for by sales to intermediate sectors, whereas the domestic forward linkage (input multiplier) measures the direct and indirect effects associated with a unitary change in the primary input of a sector.

As outlined by Boucher (1976), the coefficient of variation for linkages can be used to assess the dispersion of a sector's interdependence with the supply (demand) of other sectors. A greater coefficient of variation implies that a sector depends (connects) largely on a few sectors, whereas a sector with a low coefficient indicates that an expansion of that sector would stimulate the entire economy more evenly.

Value-added and import multipliers represent the value-added generated domestically and the leakage effect for 1-unit production, respectively. A sector with a low import multiplier indicates that most of the goods and services that are served by that sector are supplied domestically, and the leakage effect is considered small.

Multipliers of Multiregional IOA

For a more detailed illustration of the Hong Kong economy leakage from a given sector to other sectors in multiple economies, multiregional IOA (MRIOA) is used; MRIOA traces the impacts of international production and supply chains from a global perspective

(Wiedmann et al. 2011). Over the last decade, mainland China was the largest source of Hong Kong's imports, accounting for 46.4% of total imports on average (Census and Statistics Dept. 2010, 2016a).

Thus, MRIOTs for three regions, namely, Hong Kong (HK), China (CN), and the rest of the world (ROW), were compiled and used for later analysis.

The GTAP data were extracted and converted into MRIOTs for the base years 2004, 2007, and 2011. The structure of a MRIOT with n sectors is shown in Fig. 1. The block $\mathbf{Z}^{\mathbf{CN},\mathbf{HK}}$ outlines the transaction flows from industry i in China to sector j in Hong Kong. Its coefficient matrix is written as

$$\mathbf{A}^{\mathbf{CN},\mathbf{HK}} = \mathbf{Z}^{\mathbf{CN},\mathbf{HK}}\left(\hat{\mathbf{X}}^{\mathbf{HK}}\right)^{-1} \tag{5}$$

where $\hat{\mathbf{X}}^{\mathbf{HK}}$ = diagonal matrix of sectoral gross input of Hong Kong.

The diagonal blocks in the MRIOT represent the domestic IOTs from the GTAP (e.g., $\mathbf{Z}^{\mathbf{HK},\mathbf{HK}}$), and the off-diagonal blocks are constructed based on the import IOTs with intraregional bilateral trade data (Peters et al. 2011; Andrew and Peters 2013). Vectors of trade share were calculated based on the assumption that the bilateral exports are distributed according to the import structure in the importing region (Peters et al. 2011). Similar procedures were applied to the final demand, which is identified as the $\mathbf{Y}$ block. Trade shares of final consumption were also calculated using proportional distribution. The trade surplus (deficit) between imports and exports was then included as the margin under primary input (V) to retain the balance of the matrix. The expenses of international transportation were included and allocated to the regions and suppliers proportionally. The procedures for converting the GTAP database into a MRIOT are described in more detail by Peters et al. (2011) and Andrew and Peters (2013).

For the MRIOA, the configuration of backward linkage (interdependence coefficient) and total backward linkages were assessed to outline the intra- and intercountry effects, which are (1) the domestic linkage, (2) the spillover effect from Hong Kong to China, and (3) the spillover effect from Hong Kong to the rest of the world. The analyzed results are important for a small open economy to evaluate the impacts of international trade in the construction production process. In addition, the interactions between domestic linkages and leakages can also be identified.

Results and Discussion

Results of Hong Kong IOA

Fig. 2 displays the direct and domestic linkages of Hong Kong's construction sector from 1995 to 2013. The results indicate that construction had greater backward linkages than forward linkages, meaning the construction sector had a relatively strong influence in spurring other sectoral activities. The low forward linkages are attributed to the majority of construction outputs being delivered as final demand (capital investment), rather than intermediate inputs for other sectors.

The results in Fig. 2(a) indicate that construction experienced a minor decline in intermediate input shares from 0.57 in 1995 to 0.52 in 2013, and its domestic linkages dropped by 10.92% from 1.74 to 1.55. Among the 10 sectors, construction ranked first in 1995 but fell to third place by 2005, after transport and storage and wholesale and retail trade (Supplemental Data Table S5), regarding the domestic linkage. Thus, the influence of the construction sector in stimulating Hong Kong's domestic economy weakened over time. The coefficient of variation for construction domestic backward and forward linkages and the key contributors to the domestic backward linkages (with larger interdependence coefficient) are summarized in Table 1. Construction had a smaller coefficient of variation for backward linkages and ranked eighth in forward linkage. This reflects that construction has a widespread interrelationship with supplying sectors, but its output products are used in a limited number of sectors.

Over 90% of construction domestic backward linkages were derived from three sectors, and manufacturing had the largest interdependence coefficient other than construction itself. Wholesale and retail trade outstripped transport and storage in 2005 as the third-biggest contributor. The remaining seven sectors contributed 9.36% of the linkages on average. Even though construction is in a position to induce economic activity in numerous sectors, the main beneficiaries were construction and manufacturing.

Selection of Economies for Comparative Analysis

To examine the relative economic significance of Hong Kong's construction sector, an in-depth comparison with economies of similar economic structure, trade openness, fixed capital investment, and government size was conducted. Eight economies were nominated

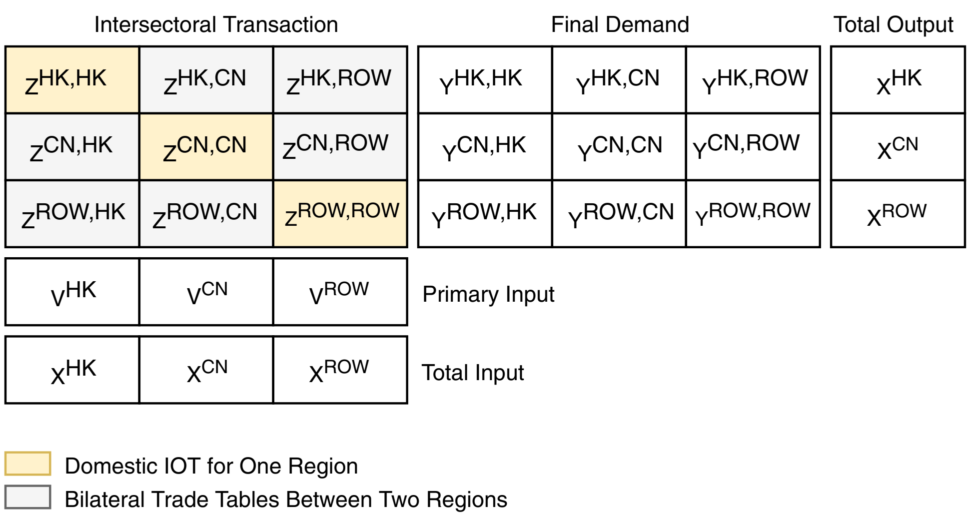
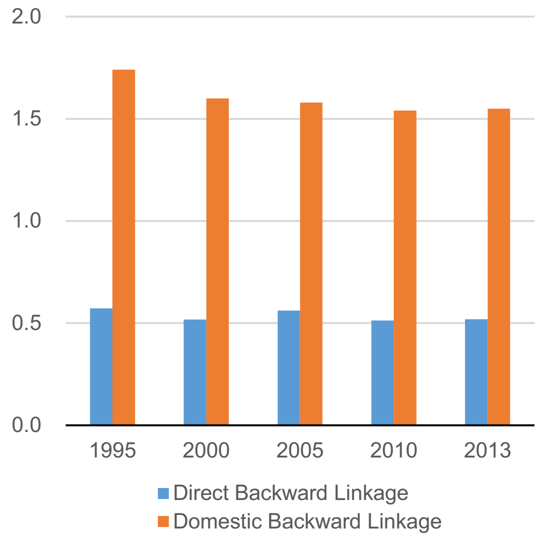


Fig. 1. Structure of proposed MRIOT.



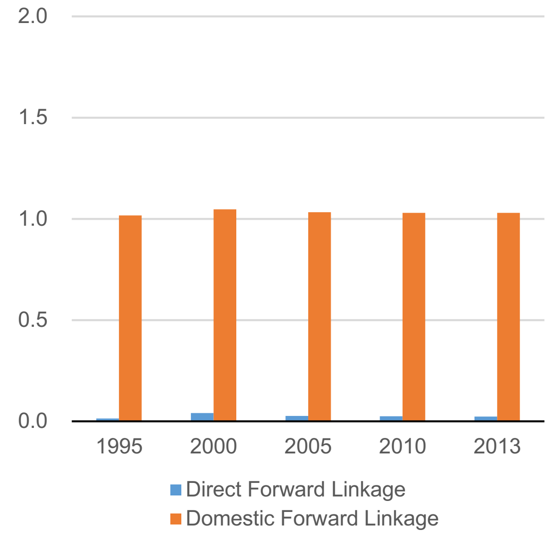


Fig. 2. Direct and domestic linkages of Hong Kong construction (1995–2013): (a) direct and domestic backward linkages; and (b) direct and domestic forward linkages.

Table 1. Coefficient of variation for Hong Kong construction linkages and key contributors

Year	Coefficient of variation and rank[a]		Key contributors[b] and share of contribution[c]
	Domestic BL	Domestic FL	
1995	2.05 (1/10)	3.11 (9/10)	Con, Manu, Finan (84.50%)
2000	1.99 (1/10)	3.02 (8/10)	Con, Manu, Trans (91.89%)
2005	2.01 (1/10)	3.06 (8/10)	Con, Manu, Trade (92.54%)
2010	2.05 (1/10)	3.07 (8/10)	Con, Manu, Trade (92.10%)
2013	2.04 (1/10)	3.07 (8/10)	Con, Manu, Trade (92.17%)

Note: BL = backward linkage; Con = construction; Finan = financing and insurance; FL = forward linkage; Manu = manufacturing; and Trans = transport and storage.
[a]Figures in parentheses represents the ascending ranking order of construction.
[b]Top-three sectors contributing the largest values in construction domestic backward linkages.
[c]Total percentage of domestic backward linkages generated by the key contributors.

from 36 advanced economies classified by the International Monetary Fund (IMF) in 2014 that complied with the following criteria: (1) share of service sector exceeded 75% of the GDP (2013 figure), (2) similar merchandise trade (percentage of GDP), (3) similar gross capital formation (percentage of GDP), and (4) similar government final consumption expenditure (percentage of GDP) with Hong Kong (average values from 2010 to 2014). The nominated economies were Belgium, Cyprus, France, Luxembourg, Malta, the Netherlands, Singapore, and the United States. Six economies were further selected to represent the small state (Cyprus), large economies (France and the United States), and economies in between (Belgium, the Netherlands, and Singapore).

The IOTs of these economies were released by the Organization for Economic Cooperation and Development (OECD) Statistics, the Singapore Department of Statistics, and the U.S. Bureau of Economic Analysis (BEA). Direct and domestic linkages were derived from technical coefficient matrices (total) and inverse matrices (domestic), respectively. As the sectoral classification varies across different data sources, sectoral aggregation and recalculation were performed for consistency and ease of comparison.

Among the selected economies, Singapore is most similar to Hong Kong regarding economic scale, economic structure, and trade volume. Both economies are characterized as free-market economies that are highly dependent on international trade (Zimring et al. 2010). Leakage analysis of Singapore was conducted and compared with Hong Kong in a comprehensive approach. First, Singapore's official IOTs for the years 2000, 2005, 2007, and 2010 were used for linkage and multiplier comparisons. Sectoral classification for Singapore is similar to Hong Kong's IOTs and remained untouched. Second, MRIOTs of Singapore for the years 2004, 2007, and 2011 were converted from the GTAP database, following the same procedures as that for Hong Kong. Two regions were proposed as Singapore (SGP) and ROW for the Singapore MRIOA to address the domestic linkage and the spillover effect from Singapore to other economies.

Direct Backward Linkages

As indicated in previous studies, the construction sector performs well in inducing economic growth with its strong pull potentials, but it has relatively weaker push effects (Bon and Pietroforte 1990; Giang and Pheng 2011). Hence, the following comparisons primarily focus on the production process, regarding backward linkages. Table 2 presents the direct backward linkages from 1995 to 2013 and the average direct inputs from selected sectors for 1-unit production over the considered period.

On average, the United States presents the lowest construction direct backward linkage of 0.45, whereas Singapore has the highest value at 0.72. Hong Kong lies in between the two with a value of 0.54. There is no discernible pattern of changing direct backward linkages of the seven economies collectively from 1995 to 2013. The results indicate an increase for Belgium and Cyprus; no change for France, the Netherlands, and Hong Kong; and a decrease for Singapore and the United States. The upward trends for Belgium and Cyprus are attributable to the steady growth of construction

J. Manage. Eng., 2019, 35(1): 04018054

Table 2. Direct backward linkage of construction sector in various economies (1995–2013)

	Direct backward linkage[a]								Average contribution[b]		
Economy	1995	2000	2005	2007	2010	2011	2012	2013	Manufacturing	Service[c]	Construction
Belgium	0.66	0.68	0.69	0.69	0.71	0.71	—	—	0.23	0.20	0.25
Cyprus	0.48	0.49	0.53	0.55	0.58	0.62	—	—	0.32	0.13	0.07
France	0.53	0.56	0.56	0.56	0.54	0.54	—	—	0.21	0.21	0.12
Hong Kong	0.57	0.52	0.56	—	0.51	—	—	0.52	0.32	0.15	0.00
Netherlands	0.65	0.65	0.63	0.64	0.63	0.63	—	—	0.21	0.20	0.21
Singapore	—	0.54	0.79	0.79	0.73	—	0.74	0.75	0.26	0.12	0.33
United States	—	0.48	0.47	0.44	0.44	0.44	0.43	0.43	0.24	0.19	0.00

Source: Data from BEA (2018a); OECD Statistics (2017b); Singapore Dept. of Statistics (2010, 2012, 2014, 2017b, c).
[a]The proportion of intermediate inputs over total inputs of a sector.
[b]Average figures of direct inputs (abstract values) from manufacturing, service, and construction.
[c]Consists of wholesale and retail trade, transport and storage, information and communications, financing and insurance, professional and support activities, and other services.

inputs (construction and service inputs). The downward trends for Singapore and the United States are attributed to the declining service (manufacturing) inputs (Supplemental Data Fig. S1).

The diverse results for intermediate input composition are inconsistent with those from previous studies (Bon 2000; Pietroforte and Gregori 2003; Pietroforte et al. 2009), which claim a constancy or a minor decline trend, along with shrinking contributions from manufacturing and continuous growth in service inputs over time (i.e., Demark and France from the 1970s to the 1990s, and the United States from the 1950s to 2002). In this study, no obvious decline in manufacturing inputs (except for the United States) or increase in service inputs (other than for Cyprus) was found. The inconsistency between the observed trends and the previous findings is largely related to the examined time frame; for example, France showed a steady decline of manufacturing inputs (input coefficient dropped from 0.30 to 0.21) with an increasing share of service inputs (from 0.15 to 0.19) from the 1970s to 1990s, as observed by Pietroforte and Gregori (2003). The share of manufacturing inputs and service inputs remained steady during 1995–2013 (input coefficients both stayed at 0.21) in this study, indicating that the construction sector in France experienced technological changes in the production process from the 1970s to 1990s, then appeared to be stabilized after 1995.

Another noteworthy result is that manufacturing products were no longer the leading intermediate inputs. France and the Netherlands exhibited equal shares of manufacturing and service inputs within each of their economies. As suggested by Pietroforte and Gregori (2003), growing inputs from knowledge-based services are required to cope with the increasing complexity of modern construction projects and the shifting trend from in-house to subcontracting for general contractors (Gundes 2011).

The sum of manufacturing and service inputs of each of the seven economies were found to be fairly similar to one another. This means an economy with a larger input coefficient of construction would eventually have a higher direct backward linkage, as in the case in Belgium and Singapore. However, the underestimation of the construction input coefficient of Hong Kong and the United States may relate to the procedures of data collection. In IOTs, subcontractors are not separated from the main contractors, and the subcontracting activities (depicted by the construction input coefficient) are excluded from the transaction flows.

The composition of Hong Kong intermediate inputs remained fairly steady from 1995 to 2013, indicating that more or less homogeneous inputs were used. Polenske and Sivitanides (1990) and Pietroforte et al. (2009) outlined a few factors that should be considered in discussing the variability of input structure, including the composition of construction activities, the differential price movements of inputs, cost structures, and the applied technologies. Nevertheless, these factors are often interconnected and inseparable.

The construction works in Hong Kong can be broadly classified as buildings (including residential, commercial, and industrial buildings) and structures and facilities (including transportation, utilities, and other facilities) according to the official statistics. The composition of construction works was dominated by the buildings subsector, and its market share reduced gradually from 77.1% in 2000 to 53.1% in 2013 (Supplemental Data Fig. S2). Meanwhile, the input coefficients from manufacturing were slightly larger in 2000 and 2005 (0.35) than in other years (0.32) (Supplemental Data Fig. S1). The shifting composition of construction works can be considered to have affected the input structure of the construction sector.

Regarding the price variation of construction costs, the overall growth rates in material costs (96.9%) were more incremental than labor costs (35.5%) from 1997 to 2013 compared with the cost indexes (Supplemental Data Table S6). Although this change was not reflected in the input structure, the proportion of intermediate inputs (largely related to materials, ranging from 0.57 to 0.51) and value-added (employee compensation is the dominant component) varied slightly over the considered period. The discussion on prices should encompass the effects of productivity and applied technologies to provide a full picture.

Prefabrication techniques have been progressively adopted in Hong Kong's construction sector to enhance productivity and buildability (Jaillon and Poon 2009; Liu et al. 2017; Li et al. 2018). Based on the case studies in Hong Kong, prefabrication techniques are believed to reduce labor costs (by 9% in one project), but the overall construction cost is slightly higher than that of conventional construction. This may be due to the higher transportation cost of the precast components (Jaillon and Poon 2009), and this increase should be revealed as parts of the input coefficients of the wholesale and retail trade and transport and storage sectors. However, projects adopting prefabrication techniques represent a small portion of the construction sector; hence, the changes in the cost structure of these projects are considered to have minor impacts on the overall input structure of the construction sector. Construction cost breakdowns, the productivity of other construction work types, and a more disaggregated IOT are required to reveal greater variability of input coefficients for the construction sector.

Domestic Backward Linkages

Table 3 summarizes the domestic backward linkages from 1995 to 2013 and the leading three sectors that construction depended on the most. The figures in parentheses in Table 3 represent the percentage of domestic backward linkages generated by these sectors. The results reveal an increase for Belgium, Cyprus, and Singapore; static for France and the Netherlands; and a minor decrease for the United States and Hong Kong. Similar to direct linkages, these observed trends are somewhat inconsistent with previous studies (Bon and Pietroforte 1990; Pietroforte and Gregori 2003), which have stated that the economic contribution of the construction sector tends to decline or stay flat over time for developed economies. Again, this variance may relate to the different time frames used in these studies.

Among the seven economies, Belgium and Singapore had higher domestic linkages, exceeding 2.0. Cyprus and Hong Kong had lower values, averaging 1.56 and 1.60, respectively. There is no clear distinction between the outcomes of large and small economies; France and the United States were found to have lower domestic linkages than Belgium and Singapore but higher domestic linkages than Hong Kong. This observation differs from the findings of Dietzenbacher (2002) that small economies tend to have a larger dependence on foreign inputs, resulting in smaller domestic backward linkages, although Pietroforte and Gregori (2003) argued that the level of industrialization and the interdependence of construction and manufacturing are the main factors affecting the magnitude of the construction output multiplier. Their results revealed that the output multipliers of Japan, Germany, Denmark, and the Netherlands are relatively larger than those of France and the United States. A similar result is presented by Ilhan and Yaman (2011); the output multipliers of some small economies (Finland, the Netherlands, and Slovenia) are larger than that of France. In this study, the results of these seven compared economies were unable to demonstrate the distinctive effect caused by imports and the dependence on the manufacturing sector because the selected economies are all characterized as service-oriented economies (share of service sectors exceeds 75% of the GDP) with high trade volume. Instead, the results in Table 3 show that construction was the leading contributor to itself, and the influence of subcontracting outperformed the leakage effects of imported intermediate inputs (Supplemental Data Table S7), as shown in the cases of Belgium, France, the Netherlands, and Singapore.

By referring to the intermediate import ratio, which is used to illustrate the ratio of intermediate import inputs over the total intermediate demand for a specific sector, it is possible to investigate the leakage effect. Large economies possess a smaller intermediate import ratio than small economies, especially for the manufacturing sector (Supplemental Data Table S8). Among the smaller economies, Singapore (0.81 on average) and Hong Kong (0.86) were found to have much greater intermediate import ratios than the others (from 0.47 to 0.56) in manufacturing goods. Once again, this outcome indicates that the impact of the leakage on the economic influence of the construction sector varies in different economies. More related explanations of leakage measures are provided in the following section.

The domestic linkages of construction were broken down to investigate the key contributors that construction depends on most. The results demonstrate that over 84% of the domestic linkages were generated by the top-three sectors with larger coefficients. Construction can be considered self-dependent, in that 65.76% on average of the domestic linkages were generated by construction itself. The levels of self-dependence in the selected economies were found to be close to each other, ranging from the lowest ratio of 56.04% for the United States in 2000 to the highest ratio of 79.56% for Singapore in 2007 (Supplemental Data Fig. S3). Manufacturing was the second key contributor (15.03% on average), and professional and support activities ranked third (except for Cyprus and Hong Kong, in which wholesale and retail trade ranked third). These results show that the production structures of the construction sector exhibit many similarities between the selected economies, regardless of the scale of domestic backward linkages.

A positive relationship between the domestic backward linkages and the input coefficients of construction was found (Table 2). Economies with larger construction input coefficients had higher domestic backward linkages, such as for Belgium and Singapore. Because the composition of induced activities is similar to one another, if more construction activities (caused by subcontracting) are involved for the same demand, then the resultant economic effect would be expected to amplify and reflect on the domestic backward linkages.

For Hong Kong, the interdependence coefficients of the construction and the service sectors stayed at 1.0 and 0.20 from 1995 to 2013. This indicates that the dependence on services remained at a lower level. The interdependence coefficients of manufacturing and construction domestic backward linkage experienced minor declines

Table 3. Domestic backward linkage of construction sector in various economies (1995–2013)

Economy	Share of GDP[a]		Domestic backward linkage[b]								Key contributors[c] and contribution share[d]
	1995	2013	1995	2000	2005	2007	2010	2011	2012	2013	2010/2011/2013
Belgium	5.27	5.56	2.04	2.00	2.12	2.15	2.18	2.17	—	—	Con, Manu, Prof (86.69%)
Cyprus	9.31	3.58	1.41	1.46	1.55	1.58	1.66	1.69	—	—	Con, Manu, Trade (90.77%)
France	5.32	5.94	1.80	1.84	1.86	1.87	1.80	1.81	—	—	Con, Manu, Prof (86.61%)
Hong Kong	5.06	3.97	1.74	1.61	1.59	—	1.54	—	—	1.55	Con, Manu, Trade (92.14%)
Netherlands	5.31	4.50	1.87	1.90	1.92	1.93	1.92	1.92	—	—	Con, Manu, Prof (85.32%)
Singapore	6.31	4.79	—	1.41	2.18	2.16	2.08	—	2.14	2.16	Con, Manu, Prof (91.86%)
United States	4.16	3.84	—	1.79	1.77	1.72	1.69	1.69	1.68	1.69	Con, Manu, Trade (83.99%)

Source: Data from BEA (2018b); CYSTAT (2017); OECD Statistics (2017a, b); Singapore Dept. of Statistics (2010, 2012, 2014, 2017a, b, c).
Note: Con = construction; Manu = manufacturing; Prof = professional and support activities; and Trade = wholesale and retail trade.
[a]The percentage contribution of construction to GDP at basic prices.
[b]The direct and indirect effects associated with a unitary change in final demand.
[c]Top-three sectors contributing the largest values in construction domestic backward linkage.
[d]Total percentage of domestic backward linkage generated by the key contributors.

over the years, but despite that, the share of manufacturing intermediate inputs remained constant. This implies that the leakage of imported goods may be the main cause of the declining influence of construction in stimulating economic growth. The impact of leakage involved in the construction activities of Hong Kong is examined along with Singapore in the next section.

Leakage Measures

Measures related to construction leakages were derived from both IOA and MRIOA. Table 4 summarizes the output, import, and value-added multipliers from 1995 to 2013 as parts of the IOA. The import multiplier represents the leak-out share, whereas the value-added multiplier denotes the intraregional effect for 1-unit production, given that the values of these two multipliers should add up to close to 1 (tax multiplier is negligible and excluded in Table 4).

The results show that the average values of value-added and import multipliers were the same for Hong Kong and Singapore (0.58 and 0.42, respectively). Although the values for Singapore's import multiplier remained stable, Hong Kong's import multipliers increased by 33% from 0.33 in 1995 to 0.44 in 2013. The economic influence of construction in Hong Kong in 2010 was weaker than in Singapore, according to their output multipliers of 1.54 and 2.08, respectively. The results for manufacturing were also compared because this sector had the largest interdependence coefficient (other than construction). Singapore's manufacturing output multiplier, averaging 1.34, surpassed that of Hong Kong at 1.15, whereas Singapore's import multiplier, averaging 0.63, was smaller than that of Hong Kong at 0.93. These observations indicate that Hong Kong's construction sector relied more heavily on imported manufacturing products, and the economic influence of the construction activities dropped as the leakage amplified from 1995 to 2013.

Nest, MRIOA was used to reveal the domestic linkage and leakage in the construction production process from a global perspective and the interaction between these two indicators over the period 2004–2011. Fig. 3(a) shows that a 1-unit increase in the final demand of Hong Kong's construction sector was able to generate 2.89–2.93 units of output. The influence of construction on Hong Kong's economy remained constant with 1.74–1.78 output units, and its influence on other regions through international trade remained in the range of 1.11–1.19 output units. Overall, 38.37–40.55% of economic output leaked abroad as spillover. Regarding leakage composition, 25.00% flowed to China, and the remaining went to other economies.

Fig. 3(b) reveals that Singapore's total backward linkages and leakages were both greater those that of Hong Kong. One unit of construction final demand in Singapore induced 3.27–3.33 units of output globally, and 30.06%–37.62% of the economic contribution leaked out to other economies. Yet a decreasing trend in leakage is observed because the output multiplier to the Singapore economy increased from 2.08 in 2004 to 2.30 in 2011, indicating that more local activities were involved in the construction production process per unit of final demand by 2011. The results echo the trends in merchandise trade in both economies. Although Hong Kong experienced a 40% increase in merchandise trade (as a share of GDP) from 1995 to 2013, Singapore experienced a continuous decline in trade (Supplemental Data Fig. S4).

The key contributors that the construction sector depended on the most are outlined in Table 5. Construction itself was the leading contributor. The construction coefficient for Singapore outperformed that of Hong Kong by 0.68–0.80 output units. This is due to the growth of subcontracting activities occurring within Singapore and the underestimated subcontracting transactions in Hong Kong. Coefficients relating to manufacturing amounted to 26.89% (Singapore) and 38.86% (Hong Kong) of the total backward linkage on average. For Hong Kong, the reliance on abroad manufacturing and service sectors remained relatively stable over time. Whereas in Singapore, the dependence on manufacturing (ROW) dropped by 19.63% from 2004 to 2011, and it was substituted by the use of local supplies. In other words, the decreased dependence on imports and the growth of subcontracting activities were the main drivers for the increased economic influence of Singapore's construction sector.

Other than for manufacturing, the results demonstrate a relatively stronger interrelationship between construction and professional and support activities in Singapore, whereas Hong Kong had a higher dependence on wholesale and retail trade and transport and storage. Considering the increased reliance on imports, additional expenses in transport and wholesale distribution were incurred, reflected as the dependence on these two sectors in Hong Kong.

Table 4. Construction multipliers for Hong Kong and Singapore (1995–2013)

Economy	Sector	Multiplier	Year 1995	2000	2005	2007	2010	2013	Average
Hong Kong	Construction	Output[a]	1.74	1.60	1.58	—	1.54	1.55	—
		Value-added[b]	0.66	0.59	0.53	—	0.57	0.56	0.58
		Import[c]	0.33	0.40	0.46	—	0.43	0.44	0.42
	Manufacturing	Output	1.31	1.17	1.09	—	1.09	1.07	—
		Value-added	0.18	0.09	0.04	—	0.03	0.02	0.07
		Import	0.81	0.91	0.96	—	0.97	0.98	0.93
Singapore	Construction	Output	—	1.41	2.18	2.16	2.08	—	—
		Value-added	—	0.63	0.55	0.53	0.61	—	0.58
		Import	—	0.37	0.45	0.47	0.39	—	0.42
	Manufacturing[d]	Output	—	1.23	1.28	1.42	1.42	—	—
		Value-added	—	0.35	0.37	0.42	0.36	—	0.38
		Import	—	0.65	0.63	0.58	0.64	—	0.62

Source: Data from Singapore Dept. of Statistics (2010, 2012, 2014, 2017b).
[a]Induced direct and indirect effects associated with a unitary change in final demand, also known as domestic backward linkage.
[b]The value of value-added generated domestically for 1-unit production.
[c]The value of import leaking out the economy for 1-unit production.
[d]Figures of manufacturing in 2000, 2005, and 2007 representing the manufacturing (non-oil) sector.

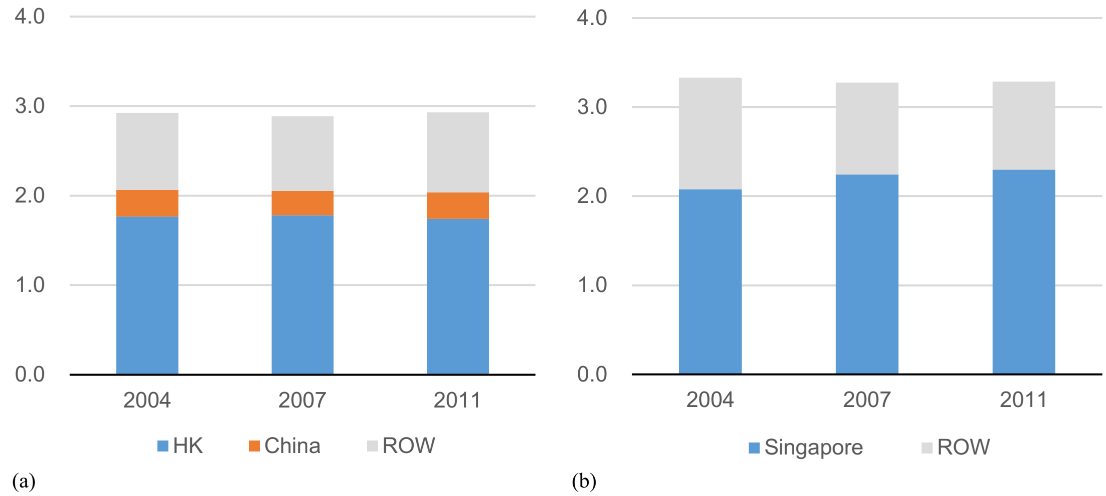


Fig. 3. Construction output multipliers of MRIOA (2004–2011): (a) Hong Kong MRIO; and (b) Singapore MRIO.

Table 5. Interdependence coefficient and contribution share of key contributors (2004–2011)

Economy	Sector	Interdependence coefficient[a]			Share of sectoral dependencies[b]		
		2004	2007	2011	2004	2007	2011
HK MRIOTs	HK construction	1.00	1.00	1.00	0.34	0.35	0.34
	ROW manufacturing	0.57	0.55	0.59	0.20	0.19	0.20
	HK manufacturing	0.35	0.35	0.34	0.12	0.12	0.11
	CN manufacturing	0.23	0.21	0.23	0.08	0.07	0.08
	HK trade	0.18	0.19	0.18	0.06	0.06	0.06
	HK transport	0.13	0.14	0.13	0.05	0.05	0.04
	ROW profession	0.08	0.08	0.08	0.03	0.03	0.03
SGP MRIOTs	SGP construction	1.68	1.77	1.80	0.50	0.54	0.55
	ROW manufacturing	0.84	0.67	0.66	0.25	0.21	0.20
	SGP manufacturing	0.14	0.17	0.18	0.04	0.05	0.05
	SGP profession	0.10	0.11	0.12	0.03	0.03	0.04
	ROW profession	0.11	0.09	0.08	0.03	0.03	0.02
	ROW trade	0.09	0.08	0.07	0.03	0.02	0.02

Note: Profession = professional and support activities; Trade = wholesale and retail trade; and Transport = transport and storage.
[a]The direct and indirect effects contributed by a given sector with a unitary change in construction final demand.
[b]The percentage of contribution from a given sector to construction total backward linkage.

A cost-breakdown analysis of construction works, along with more disaggregated MRIOTs for Singapore and Hong Kong, would assist in revealing greater variability of interdependence and leakage for the construction sector.

Conclusions

The present analysis is oriented toward understanding the economic influence and leakage of the construction sector in a small and open economy from a global perspective. This is particularly relevant to the declining economic importance of the construction sector resulting from the increasing separation of production and consumption activities in the process of globalization. The empirical application is based on the IOTs and MRIOTs for Hong Kong during the period 1995–2013. The findings reveal that the influence of Hong Kong's construction sector in stimulating economic growth decreased by 10.92% from 1995 to 2013 due to the intensifying leakages through international trade. The analyzed outcomes provide a basis for informing the Hong Kong government in decision making regarding resource allocation and strategic planning.

The measures of linkage indicate that the construction sector is one of the most influential sectors in stimulating Hong Kong's economic growth due to its widespread interrelationship with other sectors. The growing importance of the service sectors was found to have no obvious impact on the construction sector's influence. The increase in imported manufacturing goods is anticipated to be the main cause of the declining importance of the construction sector. Its influence in stimulating economic growth decreased from 1.74 output units in 1995 to 1.55 units in 2013 for a 1-unit increase in final demand.

Along with the six economies studied for comparison, the analyzed results exhibit similar production structures across each of the country's construction sectors, with over 84% of related transactions coming from three sectors: construction, manufacturing, and professional and support activities (or wholesale and retail trade). The difference in domestic backward linkages of the construction sector between those economies is that they are mainly influenced by the level of local subcontracting activities. It appears that economies with larger construction input coefficients in the production process tend to have higher domestic backward linkages.

The MRIOA conducted for this study provides a complete picture from a global perspective. The influence of the construction sector on the Hong Kong economy remained constant at 1.74–1.78 units of output from 2004 to 2011, whereas 1.11–1.19 units of output leaked out through imports. That is, a minor increase in the economic importance of the construction sector over time is suggested, but it is mainly related to imported intermediate inputs. Among the spillover effect, 25% of leakage flowed to China because it is the leading trading partner of Hong Kong, and 68.52% of the leakage was interconnected with manufacturing activities, both directly and indirectly.

From the viewpoint of policy planning, the measures of linkage and leakage illustrate the intersectoral and intercountry dispersion of a stimulus in a specific sector. In particular, for a small and open economy with a narrow economic structure, these measures constitute a perspective for understanding the economic interactions between sectors and economies. Risks associated with limited diversification in economic structure and trade can then be identified to undertake strategic planning to ensure macroeconomic stability.

At the macro level, the construction sector of Hong Kong performs well in inducing economic growth among all sectors but has relatively weaker push effects. At the meso level, investments in Hong Kong's construction sector would initiate economic growth by inducing the expansion of other sectors, such as the manufacturing, trade, and transport sectors. Yet, the dependence on the abroad manufacturing suppliers was found to be larger than that on the local suppliers. Considering the similarity between Hong Kong and Singapore (in terms of economic structure and trade openness), the results from Singapore reveal a larger economic contribution from its construction activities, with 2.08–2.30 units of output remaining within the economy. The leakage was mitigated by the use of domestic manufacturing products, subcontracting, and the dependence on local professional services in the construction production process from 2004 to 2011. Similar approaches are suggested for Hong Kong and for other small open economies to ease the dependence on foreign inputs. The selection of technologies that favor the use of local resources and labor, combined with import substitution policy, is recommended to increase the domestic transaction and mitigate the leakage. For example, the development of local building material production and prefabricated assembly work may reduce the consumption of foreign intermediate products. Also, the use of outsourcing to distribute knowledge-based services for general contractors is known to enhance the domestic intersectoral transactions. Still, the consequences of import substitution should be anticipated in the decision-making process because the trade and transportation sectors would be affected to some extent.

One limitation of this study is that the IOTs and MRIOTs are based on a 10-sector classification system, which may be suboptimal due to the unavailability of detailed sectoral data published by the Hong Kong government. A finer level of sectoral aggregation is recommended to assess the interdependence of the construction sector and the manufacturing and services sectors. Information on the productivity and cost structures of major construction works should be included for further investigation, along with verification of detailed imported manufacturing inputs and trade patterns, to accurately identify the leakage considering the composition of construction deliverables. Currently, the transaction flows of subcontractors are included as parts of contractors in Hong Kong IOTs, which may have led to an underestimation of the economic contributions of Hong Kong's construction sector. Future research addressing these limitations is suggested to better reflect the true economic contribution of the construction activities.

Acknowledgments

This study was supported by the Hong Kong Research Grant Council (25220615) and Works Branch of Development Bureau of the Hong Kong SAR government. The authors gratefully acknowledge the support.

Supplemental Data

Tables S1–S8 and Figs. S1–S4 are available online in the ASCE Library (www.ascelibrary.org).

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