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 has dropped from 1.74 in 1995 to 1.55 in 2013 per unit of final demand. In 2011, 40.55% of the economic contribution has 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, regarding resource utilization, and benefit optimization. Import substitution policy is recommended to ease foreign dependence through local production of construction products.

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Introduction

The vital role of construction activities in economic growth is well recognized (Hillebrandt 2000; Giang and Pheng 2011; Barber and El-Adaway 2013; Ho 2016; Lam and Oshodi 2016). A positive correlation between construction output and the level of economic output has been confirmed (Turin 1969; 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 fromvarious 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 US. Pietroforte et al. (2009) suggested that the declining economic importance of the US construction sector from 1947 to 2002 is strongly affected by the shrinking intermediate inputs. The decreasing contribution of manufacturing inputs is offset partially by the steady growth of service inputs. Ilhan and Yaman (2011) documented similar observations in 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 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) to the GDP is the most basic measure, whereas others claim the trade barriers, trade orientation, or 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 paper 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 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 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 one unitary 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 mining and agricultural sectors, but greater than those of 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 the

96 linkage values for Finland range from 1.70 to 1.9 from 1959 to 1985. Similar findings are
97 reported by Bon and Yashiro (1996), Pietroforte and Gregori (2003), and Ilhan and Yaman
98 (2011) with linkage values larger than 2.0 in Denmark, Finland, Hungary, the Netherlands,
99 Turkey, and Sweden prior to 2002.

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

117 To better understand the influence of Hong Kong's construction sector in stimulating
118 economic growth, this study involves analyses performed in three phases including (1)
119 investigating the linkages of the construction sector by compiling a series of IOTs for the years
120 1995, 2000, 2005, 2010, and 2013; (2) identifying the leakages of construction activities by

121 compiling multiregional IOTs (MRIOTs) for the years 2004, 2007, and 2011; and (3)
122 comparing outcomes with other economies. Measures of linkage and leakage are used to
123 quantify interdependence and trade effects for Hong Kong's construction sector, and hence to
124 discuss its changing economic importance from 1995 to 2013. The relationship between
125 domestic linkages and leakages from a global perspective is considered, and then the
126 assessments on the sectoral performance regarding linkages and leakages throughout time in
127 Hong Kong and other economies are reviewed. Also, the potential causes for the changes are
128 explored. These outcomes are expected to provide a more comprehensive view of the sector-
129 specific and overall economic benefits proceeding from construction activities in Hong Kong.
130 The coupling results with other compared economies are used to draw policy-relevant
131 observations for Hong Kong and for other small open economies that have been undergoing
132 deindustrialization.

133 The study is outlined as follows. The first section outlines the analytical framework, data
134 source in constructing Hong Kong IOTs and MRIOTs, and the commonly used measures. The
135 resulting empirical results are presented in the following section. Next, the construction
136 linkages and leakages of Hong Kong and other advanced economies are summarized and
137 compared. The shift of production structure, sectoral interdependence, and import dependence
138 over time are discussed with explanations. The paper concludes with future research
139 suggestions.

140

141 ## Materials and Methods

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

146 listed in Supplemental Data Table S1.

147 Considering the availability of statistics and the service-dominating economic structure,
148 Hong Kong IOTs have been divided into 10 sectors: (1) Agriculture, (2) Manufacturing, (3)
149 Utilities, (4) Construction, (5) Wholesale & Retail Trade, (6) Transport & Storage, (7)
150 Information & Communication, (8) Financing & Insurance, (9) Professional & Support
151 Activities, and (10) Other Services. Comparisons in sectoral classification between the Hong
152 Kong Global Trade Analysis Project (GTAP) database and other economies are summarized in
153 Supplemental Data Table S2.

154 For the compilation of intersectoral transaction tables in the years 1995, 2000, 2005, 2010,
155 and 2013, the intersectoral flow coefficients were extracted from the GTAP database on the
156 base years 1997, 2001, 2004, 2007, and 2011. The GTAP database comprises balanced,
157 harmonized data (Narayanan and Walmsley 2008; Peters et al. 2011) and inclusive sets of
158 accounts outlining the annual flows of goods and services with regional and sectoral detail for
159 140 regions (Aguiar et al. 2016). Nonetheless, the base years of GTAP are different from the
160 proposed Hong Kong IOTs. Proportional adjustment and standard RAS methods were used for
161 updating the transaction tables by reconciling and balancing the columns and rows. The basic
162 principles and procedures applied are discussed by Parikh (1979) and Toh (1998).

163 Other input data, such as intermediate consumption, value-added, final demand, imports,
164 and exports, were extracted from official statistics. Parts of the applied secondary data were
165 regrouped or separated into the appropriate classified sectors. The published statistics for
166 imports and exports are incomplete, so estimations and assumptions were applied to fill the gap
167 by referring to the composition of Singapore IOTs because Singapore's economic structure and
168 scale are similar to that of Hong Kong (Young 1992; Zimring et al. 2010). For IOT of the year
169 2010, the data of 10 principle commodities of merchandise trade (Census and Statistics Dept.
170 2016d) and merchandise trade classified by end-use category (Census and Statistics Dept.
171 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 gap. As for the imported commodities, the remaining values were redistributed to Construction, Professional& Support Activities, and Other Services.

Based on the transaction tables, three matrixes were constructed, namely a technical coefficient matrix (**A**), the Leontief matrix($\mathbf{I - A}$), and the Leontief inverse matrix($\mathbf{I - A})^{-1}$. 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

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

$$Z_{ij} = a_{ij}X_j \quad (2)$$

The estimated input coefficient for each sector is used to construct technical coefficient matrix (**A**), shown as $\mathbf{A} = [a_{ij}]$ under the assumptions that the structure of production and prices of inputs are fixed. When sectoral linkages are measured by total intermediate transactions, regardless of whether they come from domestic or international producers, they would lead to the overestimation of the linkage effect (Dietzenbacher et al. 2005; Reis and Rua 2009). In this study, imports are 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

$$\mathbf{X} = \mathbf{A^dX} + \mathbf{Y^d} \quad (3)$$

where $\mathbf{X}$ = vector of domestic gross output; and $\left(\mathbf{A^dX}\right)$ and $\mathbf{Y^d}$ = vectors of domestic

198 intermediate demand and final demand, respectively. The vector of output $\mathbf{X}$ can be solved by

199 $$\left(\mathbf{I} - \mathbf{A^d}\right)\mathbf{X} = \mathbf{Y^d}$$

200 $$\mathbf{X} = (\mathbf{I} - \mathbf{A^d})^{-1}\,\mathbf{Y^d} \quad (4)$$

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

202 Through these processes, the Leontief matrix $(\mathbf{I} - \mathbf{A^d})$ and inverse matrix $(\mathbf{I} - \mathbf{A^d})^{-1}$ of
203 Hong Kong were completed for later analysis. The concepts and methods used in the
204 compilation of IOTs are given in detail in Miller and Blair (2009). The Leontief inverse matrix
205 of Hong Kong for 2013 is shown as an example in Supplemental Data Table S3.
206
207 ***Measures of Hong Kong IOA***

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

215 From the demand side, the direct backward linkage is used to indicate the production
216 structure by revealing the intermediate inputs and value-added composition, whereas the
217 domestic backward linkage (output multiplier) illustrates the economy-wide effects of a given
218 increase in the final demand of a sector. The configuration of backward linkage
219 (interdependence coefficient) for a sector reveals its dependencies on other sectors. From the
220 supply-side perspective, the direct forward linkage highlights the share of the total output of a
221 sector accounted as sales to intermediate sectors, whereas the domestic forward linkage (input
222 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 one 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 leak out effect is considered small.

Multipliers of Multiregional IOA

For a more detailed illustration of 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), are compiled and used for later analysis.

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

$$\mathbf{A}^{\mathbf{CN,HK}} = \mathbf{Z}^{\mathbf{CN,HK}}(\widehat{\mathbf{X}}^{\mathbf{HK}})^{-\mathbf{1}} \quad (5)$$

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

<Please insert Figure1 here>

The diagonal blocks in MRIOT represent the domestic IOTs from GTAP (for example, $\mathbf{Z}^{\mathbf{HK,HK}}$), 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 **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 an MRIOT are described in more detail in Peters et al. (2011) and Andrew and Peters (2013).

For the MRIOA, the configuration of backward linkage (interdependence coefficient) and total backward linkages are assessed to outline the intracountry effect and the intercountry effect, 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 has greater backward linkages than forward

linkages, meaning the construction sector has 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.

<Please insert Figure 2 here>

The results in Fig. 2(a) indicate that Construction has experienced a minor decline in intermediate input shares from 0.57 in 1995 to 0.52 in 2013, and its domestic linkages have dropped by 10.92% from 1.74 to 1.55. Among the 10 sectors, Construction ranks first in 1995 but falls to third place by 2005, after Transport & Storage and Wholesale & Retail Trade (Supplemental Data Table S5), regarding the domestic linkage. Thus, the influence of the construction sector in stimulating Hong Kong's domestic economy has weakened over time. The coefficient of variation for Construction domestic backward and forward linkages, along with key contributors to the domestic backward linkages (with larger interdependence coefficient), are summarized in Table 1. Construction has smaller coefficient of variation for backward linkages and ranks eighth place 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.

<Please insert Table 1 here>

Over 90% of Construction domestic backward linkages are derived from three sectors, and Manufacturing has the largest interdependence coefficient other than Construction itself. Wholesale & Retail Trade outstripped Transport & Storage in 2005 as the third biggest contributor. The remaining seven sectors have 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 are Construction and Manufacturing.

Selection of Economies for Comparative Analysis

299 To examine the relative economic significance of Hong Kong's construction sector, an in-depth
300 comparison with economies of similar economic structure, trade openness, fixed capital
301 investment, and government size was conducted. Eight economies were nominated from 36
302 advanced economies classified by the International Monetary Fund (IMF) in 2014 that
303 complied with the following criteria: (1) share of service sector exceeds 75% of the GDP (2013
304 figure), (2) similar merchandise trade (percentage of GDP), (3) similar gross capital formation
305 (percentage of GDP), and (4) similar government final consumption expenditure (percentage
306 of GDP) with Hong Kong (average values from 2010 to 2014). The nominated economies were
307 Belgium, Cyprus, France, Luxembourg, Malta, the Netherlands, Singapore, and the US. Six
308 economies were further selected to represent the small state (Cyprus), large economies (France
309 and the US), and economies in between (Belgium, the Netherlands, and Singapore).
310 The IOTs of these economies were released by the Organization for Economic Cooperation
311 and Development (OECD) Statistics, the Singapore Department of Statistics, and the US
312 Bureau of Economic Analysis (BEA). Direct and domestic linkages were derived from
313 technical coefficient matrices (total) and inverse matrices (domestic), respectively. As the
314 sectoral classification varies across different data sources, sectoral aggregation and
315 recalculation were performed for consistency and ease of comparison.
316 Among the selected economies, Singapore is most similar to Hong Kong regarding
317 economic scale, economic structure, and trade volume. Both economies are characterized as
318 free-market economies that are highly dependent on international trade (Zimring et al. 2010).
319 Leakage analysis of Singapore was conducted and compared with Hong Kong in a
320 comprehensive approach. First, Singapore's official IOTs for the years 2000, 2005, 2007, and
321 2010 were used for linkage and multiplier comparisons. Sectoral classification for Singapore
322 is similar to Hong Kong's IOTs and remains untouched. Second, MRIOTs of Singapore for the
323 years 2004, 2007, and 2011 were converted from GTAP database, following the same
324 procedures as that of Hong Kong. Two regions were proposed as Singapore (SGP) and ROW

for 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 one unit production over the considered period.

<Please insert Table 2 here>

On average, the US 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 US. The upward trends for Belgium and Cyprus are mainly driven by the steady growth of Construction inputs (Construction and Service inputs). The downward trends for Singapore and the US 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, France from the 1970s to the 1990s, and the US from the 1950s to 2002). In this study, there is no obvious decline in Manufacturing inputs (except for the US), or increase in Service inputs (other than Cyprus).

351 The inconsistency between the observed trends with the previous findings is largely related to
352 the examined time frame; for example, France shows a steady decline of Manufacturing inputs
353 (input coefficient drops from 0.30 to 0.21) with the increasing share of Service inputs (from
354 0.15 to 0.19) from the 1970s to 1990s, as observed by Pietroforte and Gregori (2003). The share
355 of Manufacturing inputs and Service inputs remain steady during 1995–2013 (input
356 coefficients both stay as 0.21) from this study, indicating that the construction sector in France
357 has experienced technological changes in the production process from the 1970s to 1990s, and
358 then appeared to be stabilized after 1995.

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

365 The sum of Manufacturing and Service inputs of each of the seven economies are fairly
366 similar to one another. This means an economy with a larger input coefficient of Construction
367 would eventually have a higher direct backward linkage, as in the case in Belgium and
368 Singapore. However, the underestimation of Construction input coefficient of Hong Kong and
369 the US may relate to the procedures of data collection. Subcontractors are not separated from
370 the main contractors, and the subcontracting activities (depicted by Construction input
371 coefficient) are excluded from the transaction flows in IOTs.

372 The composition of Hong Kong intermediate inputs has remained fairly steady from 1995
373 to 2013, indicating more or less that homogeneous inputs are used. Polenske and Sivitanides
374 (1990) and Pietroforte et al. (2009) outlined a few factors that should be considered in
375 discussing the variability of input structure, including composition of construction activities,
376 differential price movements of inputs, cost structure, and the applied technologies.

377 Nevertheless, these factors are often interconnected and inseparable.

378 The construction works in Hong Kong can be broadly classified as buildings (including
379 residential, commercial, and industrial buildings) and structures and facilities (including
380 transportation, utilities, and other facilities) according to the official statistics. The composition
381 of construction works is dominated by the buildings subsector, and its market share has reduced
382 gradually from 77.1% in 2000 to 53.1% in 2013 (Supplemental Data Fig. S2). Meanwhile, the
383 input coefficients from Manufacturing appear to be slightly larger in the years 2000 and 2005
384 (0.35) than in other years (0.32) (Supplemental Data Fig. S1). The shifting composition of
385 construction works can be considered to affect the input structure of the construction sector.

386 Regarding the price variation of construction costs, the overall growth rates in material costs
387 (96.9%) are more incremental than labor costs (35.5%) from 1997 to 2013 compared with the
388 cost indexes (Supplemental Data Table S6). Although this change has not been reflected in the
389 input structure, the proportion of intermediate inputs (largely related to materials, ranges from
390 0.57 to 0.51) and value-added (employee compensation is the dominant component) varies
391 slightly over the considered period. The discussion on prices should encompass the effects of
392 productivity and applied technologies to provide a full picture.

393 Prefabrication techniques have been progressively adopted in Hong Kong's construction
394 sector to enhance productivity and buildability (Jaillon and Poon 2009; Liu et al. 2017; Li et
395 al. 2018). Based on the case studies in Hong Kong, prefabrication techniques are believed to
396 reduce labor costs (9% in one project), but the overall construction cost is slightly higher than
397 that of conventional construction. This may be due to the higher transportation cost of the
398 precast components (Jaillon and Poon 2009), and this increase should be revealed as parts of
399 the input coefficient of Wholesale & Retail Trade and Transport & Storage sectors. However,
400 projects adopting prefabrication techniques represent a small portion of the construction sector;
401 hence, the changes in the cost structure of these projects are considered to have minor impacts
402 on the overall input structure of the construction sector. Construction cost breakdown and

403 productivity of other construction work types, along with a more disaggregated IOT, are
404 required to reveal greater variability of input coefficients for the construction sector.
405
406 ***Domestic Backward Linkages***
407 Table 3 summarizes the domestic backward linkages from 1995 to 2013 and the leading three
408 sectors that Construction depends on the most. The figures in parentheses represent the
409 percentage of domestic backward linkages that is generated by these sectors. The results reveal
410 an increase for Belgium, Cyprus, and Singapore, static for France and the Netherlands, and a
411 minor decrease for the US and Hong Kong. Similar to direct linkages, these observed trends
412 are somehow inconsistent with previous studies (Bon and Pietroforte 1990; Pietroforte and
413 Gregori 2003), which have stated that the economic contribution of the construction sector
414 tends to decline or stay flat over time for developed economies. Again, this variance may relate
415 to the different time frames used in these studies.
416 <Please insert Table 3 here>
417 Among the seven economies, Belgium and Singapore have higher domestic linkages,
418 exceeding 2.0. Cyprus and Hong Kong have lower values averaging 1.56 and 1.60, respectively.
419 There is no clear distinction between the outcomes of large and small economies because
420 France and the US exhibit lower domestic linkages than Belgium and Singapore and higher
421 than Hong Kong. This observation differs from the findings of Dietzenbacher (2002), which
422 claimed that small economies tend to have a larger dependence on foreign inputs, resulting in
423 smaller domestic backward linkages, although Pietroforte and Gregori (2003) argued that the
424 level of industrialization and the interdependence of Construction on Manufacturing are the
425 main factors affecting the magnitude of Construction output multiplier. Their results revealed
426 that the output multipliers of Japan, Germany, Denmark, and the Netherlands are relatively
427 larger than those of France and the US. A similar result is presented by Ilhan and Yaman (2011);
428 the output multiplier 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 are 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 services sectors exceeds 75% of the GDP) with high trade volume. Instead, the results in Table 3 show that Construction is the leading contributor to itself, and the influence of subcontracting outperforms the leak out 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) are observed 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 are broken down to illustrate the key contributors that Construction depends on most. The results demonstrate that over 84% of the domestic linkages are generated by the top three sectors with larger coefficients. Construction is considered as "self-dependent," or that on average 65.76% of the domestic linkages is generated by itself. The levels of self-dependence in the selected economies are close to each other, ranging from the lowest ratio of 56.04% for the US in 2000 to the highest ratio of 79.56% for Singapore in 2007 (Supplemental Data Fig. S3). Manufacturing is the second key contributor (15.03% on average), and Professional & Support Activities ranks as third (except for Cyprus and Hong Kong, in which Wholesale & Retail Trade ranks as third). These results

455 denote that the production structures of the construction sector exhibit many similarities
456 between the selected economies, regardless of the scale of domestic backward linkages.

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

463 For Hong Kong the interdependence coefficients of Construction and of services sectors
464 stay at 1.0 and 0.20 from 1995 to 2013. This indicates that the dependence on services remains
465 at a lower level. The interdependence coefficient of Manufacturing and Construction domestic
466 backward linkage have experienced minor declines over the years, but despite that the share of
467 manufacturing intermediate inputs remain constant. This implies that the leakage of imported
468 goods may be the main cause for the declining influence of Construction in stimulating
469 economic growth. The impact of leakage involved in the construction activities of Hong Kong
470 is examined along with Singapore in the next section.
471

472 ***Leakage Measures***

473 Measures related to Construction leakages are derived from both IOA and MRIOA. Table 4
474 summarizes the output, import, and value-added multipliers from 1995 to 2013 as parts of the
475 IOA. The import multiplier represents the leak out share, whereas the value-added multiplier
476 denotes the intraregional effect for one unit production, given that the values of these two
477 multipliers should add up close to one (tax multiplier is negligible and excluded in Table 4).
478

479 <Please insert Table 4 here>

480 The results show that the average values of value-added and import multipliers are the same

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

MRIOA is 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 one unit increase in the final demand of Hong Kong's construction sector is able to generate 2.89–2.93 units of output. The influence of Construction on Hong Kong's economy remains constant with 1.74–1.78 output units, also its influence on other regions through international trades maintains in the range of 1.11–1.19 output units. Overall, 38.37–40.55% of economic output has leaked abroad as spillovers. Regarding leakage composition, 25.00% has flown to China and the remaining has gone to other economies.

<Please insert Figure 3 here>

Fig. 3(b) reveals that Singapore's total backward linkages and the leakages are both greater than that of Hong Kong. One unit of Construction final demand in Singapore can induce 3.27–3.33 units of output globally, and 30.06%–37.62% of the economic contribution leaks out to other economies. Yet a decreasing trend in leakage is observed because the output multiplier to the Singapore economy has increased from 2.08 in 2004 to 2.30 in 2011, indicating that more local activities are 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, a continuous decline in trade is 653 observed in Singapore (Supplemental Data Fig. S4).

The key contributors that Construction sector depends on the most are outlined in Table 5. Construction itself is the leading contributor. Construction coefficient of Singapore outperforms that of Hong Kong by 0.68–0.80 output unit. This is due to the growth of subcontracting activities occurring within Singapore and the underestimated subcontracting transactions in Hong Kong. Coefficients relating to Manufacturing amount 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 services sectors has remained relative stable over time. Whereas in Singapore, the dependence on Manufacturing (ROW) has dropped by 19.63% from 2004 to 2011, and it is substituted by the use of local supplies. In other words, the decreased dependence on imports and the growth of subcontracting activities are the main drivers for the increased economic influence of Singapore's construction sector.

<Please insert Table 5 here>

Other than Manufacturing, the results demonstrate a relatively stronger interrelationship between Construction and Professional & Support Activities in Singapore, whereas a higher dependence on Wholesale & Retail Trade and Transport & Storage is witnessed in Hong Kong. Considering the increased reliance on imports, additional expenses in transport and wholesale distribution are incurred and reflected as the dependence on these two sectors in Hong Kong. Cost breakdown analysis of construction works, along with the more disaggregated MRIOTs of 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

533 the construction sector in a small and open economy from a global perspective. This is
534 particularly relevant to the declining economic importance of the construction sector resulting
535 from the increasing separation between production and consumption activities in the process
536 of globalization. The empirical application is based on the IOTs and MRIOTs for Hong Kong
537 during the period 1995–2013. Findings reveal that the influence of Hong Kong's construction
538 sector in stimulating economic growth has decreased by 10.92% from 1995 to 2013 due to the
539 intensifying leakages through international trade. The analyzed outcomes provide a basis for
540 informing the Hong Kong government in resource allocation and strategic planning.

541 The measures of linkage indicate that the construction sector is one of the most influential
542 sectors in stimulating Hong Kong's economic growth due to its widespread interrelationship
543 with other sectors. The growing importance of the services sectors has no obvious impact on
544 the construction sector's influence. The increase in imported manufacturing goods is
545 anticipated to be the main cause of the declining importance of the construction sector. Its
546 influence in stimulating economic growth has decreased from 1.74 output units in 1995 to 1.55
547 units in 2013 for one unitary increase in final demand.

548 Along with the six economies studied for comparison, the analyzed results exhibit similar
549 production structures across each of the country's construction sectors, with over 84% of
550 related transactions coming from three sectors, namely Construction, Manufacturing, and
551 Professional & Support Activities (or Wholesale & Retail Trade). The difference in domestic
552 backward linkages of the construction sector between those economies is that they are mainly
553 influenced by the level of local subcontracting activities. It appears that economies with larger
554 Construction input coefficients in the production process tend to have higher domestic
555 backward linkages.

556 MRIOA provides a complete picture from a global perspective. The influence of the
557 construction sector on the Hong Kong economy remained constant at 1.74–1.78 units of output
558 from 2004 to 2011, whereas 1.11–1.19 units of output have leaked out through imports. That

559 is, a minor increase of economic importance of the construction sector over time is suggested,
560 but it is mainly related to imported intermediate inputs. Among the spillover effect, 25.00% of
561 leakage has flown to China because it is the leading trading partner of Hong Kong, and 68.52%
562 of the leakage is interconnected to manufacturing activities directly and indirectly.
563 From the viewpoint of policy planning, the measures of linkage and leakage illustrate the
564 intersectoral and intercountry dispersion of a stimulus in a specific sector. In particular for a
565 small and open economy with narrow economic structure, these measures constitute a
566 perspective for understanding the economic interactions between sectors and economies. Risks
567 associated with limited diversification in economic structure and trade can then be identified
568 to undertake strategic planning to ensure macroeconomic stability.
569 At the macro level, the construction sector of Hong Kong performs well in inducing economic
570 growth among all sectors, but with relatively weaker push effects. At the meso level,
571 investments in Hong Kong's construction sector would initiate economic growth by inducing
572 expansion of other sectors, such as the manufacturing, trade, and transport sectors. Yet, the
573 dependence on the abroad manufacturing suppliers is found to be larger than the local suppliers.
574 Considering the similarity between Hong Kong and Singapore (in terms of economic structure
575 and trade openness), the results from Singapore reveal a larger economic contribution from its
576 construction activities, with 2.08–2.30 units of output remaining within the economy. The
577 leakage is mitigated by the use of domestic manufacturing products, subcontracting, and the
578 dependence on local professional services in the construction production process from 2004 to
579 2011. Similar approaches are suggested for Hong Kong and for other small open economies to
580 ease the dependence on foreign inputs. The selection of technologies that favors the use of local
581 resources and labor, combined with import substitution policy, are recommended to increase
582 the domestic transaction and mitigate the leakage. For example, development of local building
583 material production and prefabricated assembly work may reduce the consumption of foreign
584 intermediate products. Also, the use of outsourcing to distribute knowledge-based services for

585 the general contractors is known to enhance the domestic intersectoral transaction. Still, the
586 consequences of import substitution should be anticipated in the decision-making process
587 because the trade and transportation sectors would be affected to some extent.

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

600
601

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606

607 ## Supplemental Data

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

609

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786

787 **Table 1.** Coefficient of variation for HK 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%)

788 Note: BL = backward linkage; Con = Construction; Finan = Financing & Insurance; FL = forward linkage;
789 Manu = Manufacturing; and Trans =Transport & Storage.
790 [a] Figures in parentheses represents the ascending ranking order of Construction.
791 [b] Top three sectors contributing the largest values in Construction domestic backward linkages
792 [c] Total percentage of domestic backward linkages generated by the key contributors.
793

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

Economy	Direct backward linkage[a]								Average contribution[b]		
	1995	2000	2005	2007	2010	2011	2012	2013	Manu.	Serv.[c]	Con.
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

795 Source: Data from BEA (2018a); OECD Statistics (2017b); and Singapore Dept. of Statistics (2010, 2012, 2014,
796 2017b, c).
797 [a] The proportion of intermediate inputs over total inputs of a sector.
798 [b] Average figures of direct inputs (abstract values) from Manufacturing, Service, and Construction.
799 [c] Consists of Wholesale & Retail Trade, Transport & Storage, Information & Communications, Financing &
800 Insurance, Professional and Support Activities, and Other Services.
801

802 **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] & the 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%)

803 Sources: Data from BEA (2018b); CYSTAT (2017); OECD Statistics (2017a, b); and Singapore Dept. of Statistics (2010, 2012, 2014, 2017a, b, c).
804 Note: Con = Construction; Manu = Manufacturing; Prof = Professional & Support Activities; and Trade = Wholesale & Retail Trade.
805 [a] The percentage contribution of Construction to GDP at basic prices.
806 [b] The direct and indirect effects associated with a unitary change in final demand.
807 [c] Top three sectors contributing the largest values in Construction domestic backward linkage.
808 [d] Total percentage of domestic backward linkage generated by the key contributors.
809

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

Economy	Sector	Multiplier	Year						Average
			1995	2000	2005	2007	2010	2013	
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 one unit production.

[c] The value of import leaking out the economy for one unit production.

[d] Figures of Manufacturing in 2000, 2005 and 2007 representing the manufacturing (non-oil) sector.

818 **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

819 Note: Profession = Professional & Support Activities; Trade = Wholesale & Retail Trade; and Transport =
820 Transport & Storage
821 [a] The direct and indirect effects contributed from a given sector with a unitary change in Construction final demand.
822 [b] The percentage of contribution from a given sector to Construction total backward linkage.
823

824 **Figure 1.** Structure of proposed MRIOT

825 **Figure 2.** Direct and domestic linkages of HK Construction (1995-2013)

826 **Figure 3**. Construction output multipliers of MRIOA (2004-2011)