An input-output analysis of the construction sector in emerging markets

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Construction is a major industry in fast growing countries and plays a leading role in the process of economic development. Using input-output tables, the performance of the construction sector in six emerging countries (Brazil, Russia, India, Indonesia, China and South Africa) is compared from 1995 to 2005. First, the construction performance in these developing economies, by using standard indicators based on value added, gross output, final demand and intermediate inputs, is investigated. Then, the similarity cosine index is introduced to assess structural change and differences in input expenditures between countries. This index is a useful tool for identifying input bundles that require a probing international comparison of construction performance.

Keywords: Construction cost, input-output analysis, international comparisons.

Introduction

International comparative studies have been at the core of Graham Ive's research. In his important contribution *Measuring the Competitiveness of the UK Construction Industry* (Ive *et al.*, 2004), this scholar (with S. Gruneberg, J. Meikle and D. Crosthwaite) investigates the relative position of the UK construction industry compared to that of France, Germany and the USA. International comparisons of construction performance are of great interest to practitioners, stakeholders, and particularly policymakers, but there is little agreement about how these studies should be undertaken, since sometimes results have been rather inconclusive or even contradictory. Despite much research effort, there is little agreement over what to measure and how to measure it (Bernstein, 2003; Langston, 2012). The specific difficulties in studying the construction sector are due to industry fragmentation, small firm size, low profit margins, environmental issues, the one-off nature of most projects, variations in design conditions. These problems are exacerbated in international comparisons, as it is difficult to define a standard project or activity to be compared. Further complicating factors include differences in climate, taxation, industrial relations, safety and environmental standards, available technologies and units of measurement (Best and Langston, 2006). Nonetheless, there is a vast literature that addresses the construction industry in an international context, categorized as case studies, pricing studies and macroeconomic analyses by Edkins and Winch (1999). These contributions usually build upon construction costs, labour or total factor productivity, macroeconomic and input-output data. The presented study is based on this last type of data because construction mostly assembles the products of other sectors and delivers investment goods to final demand. Input-output (hereafter IO) tables make it possible to analyse both production functions, i.e., what does the building industry need to deliver its output and the interdependencies between construction and other industries forming a national economy, i.e., how much construction contributes to economic growth.

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Since the initial contributions of Bon and Minami (1986) the IO model has been a standard tool in comparative analyses as, when this interdependence is analysed over time and across national borders, it helps us understand the changing role of the building industry in the process of economic development (Bon, 1991). Several indices have been used to assess its changing role, such as value added or intermediate inputs over gross output. For instance, Bon and Pietroforte (1990) compare the construction sector in the US, Japan, Italy and Finland and find convergence in manufacturing inputs but divergent patterns in services. Differences in production functions and linkages between industries may explain the unstable relationship between construction and GDP over time and across countries (Lewis, 2009). Since there is an extensive literature about advanced economies, this study focuses on a sample of emerging markets. The article is organized as follows. The second section introduces the standard demand-driven Leontief model. The third section outlines the role of construction in emerging economies by using standard indicators. Then the study addresses input usage, because it is interesting to assess whether construction is demanding more or less of the same amount of inputs. Initially, a very broad bundle comprising value added, manufacturing and private services is considered, as it is usually found in the literature. Although up to 37 commodities can be used in the comparison, to avoid a quite cumbersome investigation, the cosine similarity index is introduced. This index measures similarity in input utilization and makes it possible to state how, say, the Brazilian input mix is close to the Chinese one by using all available information. We conclude by outlining some methodological considerations for further research in the field of IO analysis.

Model and data

The starting point of the study is the standard IO table, the entries of which are given in monetary terms. Let X be the matrix of intermediate deliveries across the n industries, whose typical entry x_{ij} shows the delivery from sector i to sector j, y the column vector of final demand and v′ the row vector of value added.[1] The accounting identities of the industry-by-industry IO table are:

$$\mathbf{x} = \mathbf{Xu} + \mathbf{y} \tag{1}$$

$$\mathbf{x}' = \mathbf{u}'\mathbf{X} + \mathbf{v} \tag{2}$$

where $\mathbf{u}$ is the summation vector (consisting of ones) and $\mathbf{x}$ the column vector of gross output. Equations 1 and 2 must hold by definition. Nonetheless, they provide useful insights about the functioning of an economy and its sectors in a particular year. These indicators include, among others, construction gross output (value added) over domestic gross output (value added) and construction final (intermediate) demand over national final (intermediate) demand (Bon, 1988). These indices show the relevance of the construction sector in a country, but they do not describe its links in terms of inputs and deliveries to other sectors (Gregori, 2009).

Dividing the flow from one industry to another industry by the gross output of the latter we obtain the expenditure coefficient:

$$a_{ij} = x_{ij}/x_j \tag{3}$$

If we assume that all the prices are equal to one, as in the base year, then expenditure coefficients are direct input requirements too and a_{ij} gives the input from industry i that is required per unit of production in industry j. Otherwise:

$$a_{ij} = \frac{x_{ij}}{x_j} = \frac{p_{ij}q_{ij}}{p_j q_j} = \frac{p_{ij}}{p_j}\bar{a}_{ij} \tag{4}$$

where p_{ij} is the price paid by sector j for the delivery from sector i, p_j is the price for gross output q_j measured in physical units as delivery q_{ij}. The Leontief model requires compiling physical IO tables, that are hardly available, and assumes that the direct requirement matrix $\bar{A} = [\bar{a}_{ij}]$ is fixed. This is known as the proportionality assumption that is also used in monetary IO models to derive:

$$\mathbf{x} = \mathbf{Ax} + \mathbf{y} \tag{5}$$

whose solution is:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{By} \tag{6}$$

where $\mathbf{I}$ is the identity matrix, $\mathbf{B} = [b_{ij}]$ is the Leontief inverse or multiplier matrix and final demand is specified exogenously. The solution gives the output levels in each industry that are required to satisfy a given final demand. This approach is useful to assess differences in economic structures via comparisons of entries in $\mathbf{A}$ and $\mathbf{B}$ in a point in time, when price changes can be ignored. It can be shown that in an ideal setting, when each sector produces only one commodity that is sold at a single price, requirement matrices $\mathbf{A}$ and $\bar{\mathbf{A}}$ are similar, as $\mathbf{A} = \widehat{\mathbf{p}}\bar{\mathbf{A}}\widehat{\mathbf{p}}^{-1}$, and impact analyses yield identical outcomes. Pure double deflation is questionable in empirical investigations and predictions can be different when the framework is in current or constant prices (Dietzenbacher and Hoen, 1998). Nonetheless, IO coefficients in current prices tend to become more stable than those in constant prices, as pointed out by Klein (1989). Dietzenbacher and Temurshoev (2012) address this issue and find that all methods essentially provide similar results. Hence, they recommend using the simplest one, which does not require the availability of IO data in constant prices, unless these data are easily obtainable.

We have collected tables from the Organisation for Economic Co-operation and Development (OECD) IO database developed by the Economics Analysis and Statistics Division of the OECD Directorate for Science, Technology and Industry (Organisation for Economic Co-operation and Development, 2012). This database is a very useful empirical tool for structural analysis, as it describes final and intermediate flows of industry outputs according to a classification based on the ISIC Rev. 3 system that currently covers 37 sectors (see Appendix A). In line with the 1993 System of National Accounts, the database records inter-industrial transactions of goods and services (domestically produced and imported) for all OECD countries (except Iceland) and 15 non-member countries, that occurred in 1995, 2000 and 2005 or nearest years. Data are at basic prices in current local currency and US dollars. This study considers data in local currency only, as actual exchange rates are widely criticized due to excessive volatility and even if it is generally believed that international comparisons should be made in terms of purchasing power parity (PPP). A variety of approaches have been proposed to collect price data for international construction price comparisons. These build upon on input prices to construction, output prices of construction, intermediate prices, and some combination of the above (McCarthy, 2013). While the arguments in favour of construction PPP (CPPP) over exchange rates are strong, it is not possible to establish a clear superiority of CPPP (Gruneberg and Fraser, 2012). Furthermore, intermediate input PPP should reflect the costs of acquiring intermediate deliveries and match the price concept used in IO tables, i.e. basic prices without trade and transport margins. Even if some research efforts have been made in this direction by the Groningen Growth and Development Centre, for time being, there are no international IO tables in PPP. Therefore, we focus on ratios from IO tables in local currency and comparisons must be interpreted with caution. In this study a sample of important emerging market economies is considered: Brazil, Russia, India, Indonesia, China and South Africa or in short BRIICS.

The role of construction in emerging markets

The changing role of construction at various stages of development has been at the core of the debate in the field of construction economics. Turin (1969) postulates a causal relationship between building and economic growth and construction as a major industry that replaces manufacturing in driving economic growth after the first stage of development, the so-called 'middle-income country bulge' (Strassman, 1970). In his subsequent study, Turin (1978) claims that an S-shaped curve should better describe such a relationship. This is to say that construction share in GDP is always positively related with GDP per capita, first at an increasing and then at a decreasing rate. In contrast, Bon (1992) argues that the inverted U-shaped relationship should hold for both the share of construction in GDP and its volume. The so-called 'Bon curve' is still under scrutiny (Ruddock and Lopes, 2006) and a definitive answer is not available so far, since other variables such as output structure (Gruneberg, 2010) or urban population and population density can matter (Gregori and Pietroforte, 2011). Choy (2011) rejects the U-shaped relationship between construction activities and level of development when data for 205 countries, over the 1970–2005 period, are considered simultaneously. In addition, Choy claims that 'it is more appropriate to interpret the Bon curve as the explanation of variation within countries over time than as the explanation of variation across countries at a given time' (Choy, 2011, p. 707). Therefore, it is interesting to address the role of construction between and within BRIICS countries by using standard indicators such as shares in final demand, value added and gross output.

First, we must consider how developed the BRIICS economies are. According to the World Bank,[2] in 1995 the GDP per capita in PPP constant 2011 dollars is only $2111 in India and $2444 in China versus $12 032 in Russia and $10 748 in Brazil.[3] The average rate of growth during the following decade is astonishing in China with an incredible 9.1% and quite remarkable in India (4.7%) and Russia (4.3%), while it is about 1% in all other countries under consideration. However, the Russian increase is uneven and amounts to just 2% per annum in the first five-year period. In 2005 Chinese GPD per capita goes up to $5568, close to the Indonesian one ($6510 versus $5772 in 1995) but it is still about half of that in Brazil ($11 846) and South Africa ($10 611 versus $9331 in 1995). Hence, our dataset includes countries with quite different and changing standards of living.

Let us verify the importance of construction in total final demand, as shown in Table 1. This ratio declines during the 1970s and 1980s in highly developed economies with values ranging from 6% to 16% in 1990 (Pietroforte and Gregori, 2003). In 1995, only South Africa displays a very low value (5.26%), while it is quite large in other BRIICS economies varying from 10% (Russia) to 22% (China). According to Bon's theory, we should expect the increase of construction

Table 1 Construction's role in BRIICS

	Final demand			Value added			Gross output		
	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)
Brazil	13.70	13.63	7.16	8.56	8.63	4.90	8.20	7.85	4.43
Russia	14.51	10.14	n.a.	8.49	6.72	n.a.	8.49	6.93	n.a.
India	10.43	11.04	19.78	5.06	5.76	8.72	6.91	7.08	11.23
Indonesia	17.72	15.30	18.94	6.72	5.65	7.51	10.50	8.49	10.41
China	21.86	23.55	21.96	6.69	6.44	5.84	8.56	8.60	7.78
South Africa	5.26	5.94	6.08	3.15	2.95	2.42	5.22	4.74	4.24

share in poor but fast growing countries. However, values are quite stable in South Africa and China, despite very different rates of growth in GDP per capita. Otherwise, there are sudden changes as in Brazil, India and Indonesia. For instance, GDP per capita grows with the yearly rate of about 1% in Brazil and South Africa during the 1995–2005 period, while construction demand share is stable in the first country and eventually drops in the second one. This sudden change likely is due to a specific shock, since Brazil experienced a lack of business confidence after the collapse of Argentina in 2001 and a contemporaneous energy crisis.

Even within a country it is not easy to discern a direct link between growth and building activities. Let us consider India. The construction sector of this country was booming in 2005 because of increased capital investment in agriculture, mostly for civil works in rural areas, but GDP per capita grew at the very same pace in the 1990s too. Hence, we cannot claim that there is a clear-cut relationship between development and construction final demand share. This is likely due to level and growth rate effects as the considered sample includes three emerging countries, with pretty good standards of living (Brazil, Russia and South Africa), and three poor countries, one of which is booming (China). Overall less advanced economies have larger shares, but local shocks can change the picture significantly.

The supply side can be addressed in terms of value added and gross output ratios. Pietroforte and Gregori (2003) find a declining pattern during the 1970s and 1980s in leading economies with value added construction shares ranging from 5% (Germany) to 9% (Canada) in 1990. The share of Canada is close to Brazilian and Russian values in 1995, but all the figures in Table 1 appear to be comparable to the ones reported by Pietroforte and Gregori (2003). Only South Africa, whose value added is very small, is different. Table 1 shows that value added mirrors final demand shares and their respective changes are similar. For instance, in India value added ratios are very close in 1995 and 2000, while there is a large increase in 2005. The same pattern is found for final demand. Once more, we cannot find any direct relationship with growth as Indian GDP per capita consistently increased in the 1990s and beyond.

Furthermore, it is even more surprising to see the decrease in Chinese construction value added share. A possible explanation is provided by Wu and Zhang (2005), who show how the proportion of value added in construction to Chinese GDP steadily grew from the 1960s, almost doubling during the 1978–94 period and levelling off afterward. However, at the turn of the century, according to these authors 'the M&R services of China, which mainly appear in the services sector, are still weak' (Wu and Zhang, 2005, p. 911) and the construction industry mix is not yet the one that characterizes advanced economies.

A similar picture emerges when gross output proportions, that include intermediate inputs, are considered. It is well known that construction can use working capital extensively and its gross output is larger than value added, particularly in highly developed economies (Bon, 1988, Pietroforte *et al.*, 2009). Our data partially support such a claim. Intermediate inputs appear to be important in China, South Africa, Indonesia and India. In this last country gross output share is 11.23% in 2005, while value added accounts for 8.72% only. The same finding applies to Indonesia, whose shares are respectively 10.41% and 7.51%, and differences between gross output and value added for these four countries are about 2%. In contrast, Brazilian and Russian values are much closer. This pattern calls for a better understanding of input provisions as expenditures in intermediate inputs appear to diverge in BRIICS.

A simple analysis of construction's input provision

In this section we focus on direct resource utilization, that is, the expenditures incurred for purchasing the bundle of goods and services needed to create, renovate, repair or extend fixed assets in the form of building, land improvement, and other types of construction such as roads, bridges, dams and so forth. Bon (1991) argues that value added by construction can be rather small in comparison with that of other industries, given the fact that it assembles products of other sectors such as manufacturing or energy, or services such as trade and transportation, and produces investment goods for final demand. The standard index to measure the degree of industrialization is the direct backward indicator, i.e., the ratio of the value of intermediate inputs to total output (Bon, 1988). According to Pietroforte and Gregori (2003) this index is between 48% and 62% in most advanced countries. Value added shares complement the backward indicators and obviously span the 38–52% range in their dataset. In 1997 the US value added share is about 43% but it grows up to 50% in 2002 (Pietroforte *et al.*, 2009). Similar results apply in some emerging and developing countries. At the end of the last century, value added ratios are close to 50% in Turkey (Gundes, 2011), Thailand (Kofoworola and Gheewala, 2008) and Cyprus (Mehmet and Yorucu, 2008). Chinese construction appears to be different, as Wu and Zhang (2005) report a share of only 26.8% in 2000. Our sample confirms these findings to some degree. On one side Brazil and Russia behave like developed economies, with a large in-house production of material inputs and services, as their value added share varies between 50% and 54%. On the other side, some ratios are very small as in China, Indonesia and South Africa, where one unit of output requires mostly intermediate components.

The comparisons of input provision in Table 2 allow assessment of differences between countries. For instance, if the 2005 values of India and Indonesia are considered, the value added share appears to be the same (35%) but India uses less manufacturing and private services. Here we consider broad aggregates such as material (manufacturing) and immaterial (private service) inputs. The latter encompasses all the inputs (reported in Appendix A) from sectors 24 (hotels and restaurants) to 32 (other business activities), excluding 25 (transport and storage). Manufacturing is without mining. Total flows include imports, so it is possible to verify the 'make or buy' trade-off that firms face. As expected, the Chinese construction sector uses significant material inputs. In 1995, almost 55% of gross output is composed of manufactured goods. These and private service inputs are about 62% of total production in 2000. The material component is becoming more important in Indonesia and in India, whose manufacturing share increases by about 5%. In contrast, in South Africa both value added and manufacturing decrease by about 5%, while private services become very important.

Table 2 Construction expenditure shares from total flows

	Value added			Manufacturing			Private services		
	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)
Brazil	53.57	53.96	53.81	22.94	27.87	26.84	5.62	4.75	2.83
Russia	51.00	49.92	n.a.	32.67	32.78	n.a.	1.02	0.94	n.a.
India	38.17	42.49	35.28	29.27	26.77	34.03	3.29	4.78	3.59
Indonesia	34.14	33.23	35.37	36.76	38.70	43.19	6.79	7.89	7.04
China	29.92	26.82	25.57	54.92	52.56	48.63	3.10	8.91	7.69
South Africa	30.09	31.43	24.63	36.34	32.97	31.70	6.85	6.50	10.35

Table 3 Construction expenditure shares from domestic flows

	Trade and transport			Manufacturing			Private services		
	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)	1995(%)	2000(%)	2005(%)
Brazil	4.82	4.27	6.36	21.81	25.43	24.67	5.56	4.48	2.34
Russia	11.55	10.92	n.a.	27.22	25.24	n.a.	0.97	0.86	n.a.
India	16.12	10.83	12.45	27.80	23.80	29.07	3.29	4.64	3.39
Indonesia	10.79	10.93	9.91	27.01	24.43	34.13	5.91	5.40	5.14
China	7.81	7.75	6.36	51.00	48.06	43.68	3.01	8.84	7.36
South Africa	5.58	3.81	5.66	32.16	28.12	25.45	6.74	6.18	9.86

Table 3 shows the domestic content of manufacturing, private services and trade and transport. In this way it is possible to assess the importance of these flows which can produce further output and income via the Leontief multipliers. It is interesting to notice the fundamental role of trade and transport in some countries, as figures are sometimes larger than 10% (Russia and Indonesia), and even 16% in India.

Apart from Indonesia, differences between the figures of private services in Tables 2 and 3 are very small and suggest that these services are non-tradable. Here imports do not undermine multiplicative processes. This is no longer true if manufacturing in Indonesia is considered. Construction firms buy up to 14% of material inputs abroad and international leakages are relevant. This peculiar result is partially due to the financial crisis that hit this economy in 1997. Small international leakages explain the large output multipliers found by Wu and Zhang (2005) in China. It is quite unlikely that similar results would be found in Brazil and Russia, as domestic manufacturing shares are much lower.

Finally, we must mention the relevant quota of construction intra-trade in South Africa, that ranges from 12.7% to 19.5% and accounts for most of the difference between value added and intermediate inputs. This finding suggests a different industry structure with an important role of the informal sector. It is known that flexible labour practices emerged in the late 1990s in response to demand fluctuations and resulted in the use of unregulated labour-only subcontracting (van Wyk, 2003). This is reflected in the construction employment that went from 337 000 workers in September 2001 to 582 000 in September 2006 in the formal sector and from 276 000 to 424 000 in the informal sector (Statistics South Africa, 2006). This different structure materializes in Tables 2 and 3, particularly in the last observation when the share of private services is the largest.

A comparison of construction recipes in BRIICS

Tables 2 and 3 show that input provision appears to be quite diverse in the considered BRIICS countries and suggest differences in the building recipes if all the 37 inputs are considered. The use of disaggregated data is always challenging, due to differences in sources and accounting techniques. OECD tries to harmonize basic data from national statistics and this task is feasible only when large IO or supply–use matrices are available (Miller and Blair, 2009). Actually, this condition is hardly met in our sample and there are several industries with imperfect concordances, mostly in the services sectors (Organisation for Economic Co-operation and Development, 2012). Chinese tables are quite problematic in terms of private services as, for instance, computer and related activities are first included in radio, television and communication equipment, then in other business activities, and lastly, in post and telecommunications. A detailed description of these discrepancies is provided on the OECD website. With this caveat, we can proceed further in our analysis.

First, we introduce an index that allows us to assess overall differences between expenditure vectors. This indicator can be found in the literature that addresses the aggregation in IO models (Miller and Blair, 2009). Theil (1957) observes that there is no aggregation bias when all industries are characterized by a homogeneous IO structure. This condition is met 'if an additional output of one unit an additional output of one unit of any firm belonging to industry μ requires the same demand for the products of each firm of industry μ' no matter which pair of firms in these industries is chosen' (Theil, 1957, p. 118). This is a rather stringent requirement for any empirical application and the only feasible route is to devise a method for identifying quasi input-homogeneous sectors. Ward (1963) adopts a standard Euclidean distance to measure input similarity between column vectors in matrix **A**. If two sectors are perfectly input-homogeneous, the Euclidean distance is equal to zero, otherwise it is positive. There are other metrics for quantifying the divergence among cost structures such as the covariance, the Pearson correlation or even the simple inner product (Jones and Furnas, 1987). We select the cosine similarity index[4] between country i and j:

$$cs_{ij} = \frac{\sum_{l=1}^{37} a_{lc}^{i} a_{lc}^{j}}{\sqrt{\sum_{l=1}^{37} (a_{lc}^{i})^2} \sqrt{\sum_{l=1}^{37} (a_{lc}^{j})^2}} \tag{7}$$

that is a normalized inner product or the cosine of the angle between a_c^i and a_c^j. This is a simple index of similarity between two vectors and is particularly useful in a positive space, as it is with IO data, because the outcome is neatly bounded in [0,1] where 0 usually indicates unrelated ones (in a two-dimensional space the angle is equal to 90°) and 1 means exactly the same vector (the angle disappears). In-between values suggest similarity or dissimilarity. This index is preferred because it is not invariant to (almost all the) shifts. If a_c^i is increased to, say, a_c^i+0.01, the cosine similarity index changes. This occurs for any non-radial increase in coefficients. In our application this is a desirable property, since this indicator must reveal that production in country i requires a larger amount of some or even all intermediate inputs.

Table 4 Construction technology similarity indexes from total flows

		Brazil			Russia		India			Indonesia			China			South Africa	
		1995	2000	2005	1995	2000	1995	2000	2005	1995	2000	2005	1995	2000	2005	1995	2000
Brazil	2000	0.978															
	2005	0.900	0.928														
Russia	1995	0.766	0.787	0.854													
	2000	0.771	0.787	0.846	0.964												
India	1995	0.782	0.797	0.795	0.805	0.818											
	2000	0.801	0.813	0.806	0.809	0.828	0.978										
	2005	0.857	0.875	0.795	0.787	0.813	0.955	0.941									
Indonesia	1995	0.698	0.715	0.742	0.605	0.704	0.835	0.833	0.795								
	2000	0.702	0.736	0.717	0.639	0.738	0.855	0.864	0.853	0.929							
	2005	0.682	0.733	0.736	0.602	0.677	0.695	0.687	0.689	0.750	0.840						
China	1995	0.830	0.876	0.921	0.906	0.848	0.764	0.793	0.787	0.682	0.686	0.692					
	2000	0.834	0.894	0.875	0.823	0.827	0.801	0.811	0.836	0.736	0.788	0.777	0.899				
	2005	0.631	0.710	0.676	0.575	0.594	0.681	0.684	0.688	0.655	0.689	0.674	0.630	0.701			
South Africa	1995	0.851	0.868	0.745	0.625	0.651	0.717	0.711	0.845	0.653	0.643	0.555	0.685	0.744	0.569		
	2000	0.787	0.786	0.661	0.515	0.529	0.550	0.552	0.699	0.479	0.462	0.419	0.569	0.605	0.430	0.955	
	2005	0.561	0.555	0.399	0.170	0.258	0.372	0.355	0.510	0.402	0.411	0.330	0.194	0.336	0.472	0.775	0.819

The cosine similarity index is symmetric, so that results can be shown in a (lower) triangular matrix as in Tables 4 and 5. Apart from Russia, we compare each construction input provision with the other 16: two in the very same country and 14 internationally. In each country block we can see expenditure changes within the same economy. Hysteresis is prevalent and quite strong when values are close to unity, as in the case of Brazil and India. Only the Chinese input mix in 2005 appears to be quite unrelated to the previous ones, since the similarity index is quite small for both the total and domestic flows. This can be due to a real change in input provision or different accounting methods, as there are several changes in the industry classification between the first and last Chinese tables. During this time span, in addition, there are smaller but notable changes in South Africa and Indonesia.

It is also worthwhile to compare recipes between countries. If we exclude intra-country data, about 72.5% of the 120 available indices in the total flows matrix are in the 0.7–0.9 range, while only 14.2% are below 0.5. These ratios are respectively 75.8% and 12.5% in the domestic flows matrix. Most of the arrays seem to share some common inputs, even if the former are very similar (the cosine index is larger than 0.9) in just a few pairwise comparisons, such as in China and Russia in 1995. However, the change in China appears to be quite significant. If we compare Chinese values, a widespread decrease from 1995 to 2005 can be noticed. If different accounting methods do not matter, it can be argued that the Chinese construction sector has reshaped its input provision during the boom with a new structure that eventually is quite different from all the others. A similar pattern emerges in South Africa with an even larger decrease in the cosine similarity index. Actually, the smallest values appear in the last row of Table 5 and suggest that the South African construction sector changed in 2005.

Now we can introduce raw data for some interesting domestic bundles. Table 6 shows 37 input shares in Brazil, Russia and India in 2000. As shown in Tables 4 and 5, these shares can be considered as the variants of a standard recipe, as the similarity index is often close to or larger than 0.8. Differently, China and South Africa in 2005 are quite peculiar, while Indonesia is somewhere in between. Chinese and South African construction bundles are examined by taking into account both the 1995 and 2005 data.

Coefficients about Indonesia and China in 2005 are from commodity-by-commodity IO tables, while all the others are from industry-by-industry tables. These different frameworks do not seem to preclude a comparative analysis, since column vectors are not too diverse, except in few particular entries. Let us review the common items in almost all the arrays. These are wood,

Table 5 Construction technology similarity indexes from domestic flows

		Brazil			Russia		India			Indonesia			China			South Africa	
		1995	2000	2005	1995	2000	1995	2000	2005	1995	2000	2005	1995	2000	2005	1995	2000
Brazil	2000	0.978															
	2005	0.893	0.928														
Russia	1995	0.774	0.802	0.874													
	2000	0.791	0.808	0.875	0.959												
India	1995	0.804	0.819	0.812	0.849	0.882											
	2000	0.844	0.854	0.843	0.873	0.892	0.977										
	2005	0.870	0.882	0.797	0.806	0.854	0.954	0.938									
Indonesia	1995	0.661	0.659	0.732	0.568	0.682	0.732	0.733	0.693								
	2000	0.733	0.738	0.778	0.676	0.771	0.827	0.837	0.808	0.955							
	2005	0.688	0.720	0.762	0.646	0.731	0.709	0.728	0.679	0.746	0.801						
China	1995	0.821	0.877	0.926	0.914	0.854	0.760	0.799	0.757	0.615	0.696	0.694					
	2000	0.828	0.870	0.876	0.849	0.848	0.806	0.831	0.824	0.672	0.752	0.753	0.902				
	2005	0.620	0.696	0.667	0.572	0.592	0.679	0.690	0.672	0.579	0.652	0.632	0.622	0.686			
South Africa	1995	0.844	0.857	0.727	0.605	0.652	0.693	0.684	0.834	0.581	0.612	0.517	0.652	0.715	0.544		
	2000	0.764	0.761	0.623	0.475	0.509	0.521	0.525	0.688	0.426	0.444	0.387	0.521	0.517	0.400	0.953	
	2005	0.552	0.529	0.378	0.156	0.258	0.313	0.302	0.486	0.358	0.349	0.288	0.165	0.289	0.415	0.779	0.849

coke and refined petroleum products, basic metals, wholesale and transport. Chemicals and other non-metallic products can be also added to this list because, as addressed below, we can drop the last vector about South Africa in 2005.

The construction sector generally does not buy much from other private services with the exception of occasional purchases from post and telecommunications, finance, and other business services. The large values of the other business services in South Africa are due to the inclusion of renting of machinery, computer and related activities and research and development.

There are additional interesting discrepancies. For instance, construction intra-trade (row 22) is negligible or very small everywhere, except in South Africa, where it is extraordinarily important, and, to a lesser extent, in Brazil. Agricultural share is surprisingly large in China in 2005, while it reaches a reasonably normal value in India and Indonesia. This last country displays an unreliable input value for food products (5.3%) in 2005, while it is equal to zero in the previous years. Since the opposite happens with mining and quarrying, whose figures are initially larger than 5% and drop to zero in 2005, a typo is suspected. In fact, a direct inspection of the highly aggregated IO table (nine sectors) available at the Badan Pusat Statistik website confirms this hypothesis.

It is puzzling to notice no positive flow from metal products in Russia and South Africa. Russia apparently does not use any input from industry 14 (office, accounting and computing machinery) to 19 (other transport equipment). Since this country adopts a classification that is not fully harmonized with ISIC, it is very probable that all expenditures in machinery are recorded in sector 13 (machinery and equipment n.e.c). Unfortunately, OECD does not provide any explanation. This casts some doubts on available information as a zero entry means that item is not needed or it has been produced in-house. Both hypotheses are quite unrealistic. Missing values are more likely due to incomplete datasets as in the case of South Africa. Actually, the Central Statistical Service and then Statistics South Africa published IO tables until 1995 and then discontinued the series in favour of supply and use tables. Statistics South Africa has recently released a draft IO table for the year 2009 where construction is buying quite a lot of metal products and general and special machinery (Statistics South Africa, 2013). We can conjecture that OECD could not enucleate these items due to lack of data. Hence, comparisons can be misleading and it is more advisable to focus on the earlier tables only.

Table 6 Direct requirements in selected countries

Sector	Brazil 2000	Russia 2000	India 2000	Indonesia 2005	China 1995	China 2005	Sou. Afri. 1995	Sou. Afri. 2005
1: Agriculture	0.0001	0.0000	0.0204	0.0160	0.0037	0.0680	0.0022	0.0016
2: Mining	0.0021	0.0014	0.0083	0.0000	0.0257	0.0162	0.0229	0.0260
3: Food products	0.0002	0.0004	0.0007	0.0531	0.0004	0.0008	0.0032	0.0024
4: Textiles	0.0004	0.0006	0.0028	0.0002	0.0041	0.0031	0.0047	0.0031
5: Wood	0.0132	0.0198	0.0309	0.0337	0.0129	0.0248	0.0133	0.0201
6: Pulp & paper	0.0009	0.0000	0.0008	0.0022	0.0005	0.0007	0.0077	0.0000
7: Coke, petrol.	0.0122	0.0349	0.0167	0.0441	0.0177	0.0168	0.0168	0.0363
8: Chemicals	0.0164	0.0143	0.0176	0.0055	0.0119	0.0276	0.0107	0.0000
9: Rubber	0.0181	0.0000	0.0006	0.0130	0.0063	0.1078	0.0080	0.0858
10: Non-metallic	0.0854	0.0979	0.0833	0.0667	0.2490	0.0730	0.0955	0.0000
11: Basic metals	0.0447	0.0398	0.0577	0.0280	0.0708	0.0861	0.0989	0.0541
12: Metal prod.	0.0281	0.0000	0.0121	0.0731	0.0636	0.0499	0.0063	0.0000
13: Machinery	0.0067	0.0438	0.0019	0.0170	0.0447	0.0271	0.0121	0.0000
14: Office, acc.	0.0000	0.0000	0.0000	0.0003	0.0029	0.0004	0.0000	0.0000
15: Electrical	0.0182	0.0000	0.0093	0.0025	0.0066	0.0112	0.0393	0.0368
16: Radio & TVs	0.0003	0.0000	0.0004	0.0015	0.0027	0.0001	0.0001	0.0010
17: Med. Instr.	0.0025	0.0000	0.0000	0.0002	0.0018	0.0006	0.0001	0.0000
18: Vehicles	0.0007	0.0000	0.0013	0.0000	0.0023	0.0014	0.0014	0.0064
19: Other trans.	0.0001	0.0000	0.0003	0.0000	0.0016	0.0009	0.0001	0.0000
20: Oth. manuf.	0.0062	0.0011	0.0017	0.0002	0.0102	0.0045	0.0034	0.0083
21: Elect. & gas	0.0016	0.0126	0.0172	0.0004	0.0043	0.0147	0.0077	0.0044
22: Construction	0.0367	0.0075	0.0052	0.0010	0.0055	0.0014	0.1261	0.1953
23: Wholesale	0.0311	0.0626	0.0525	0.0766	0.0479	0.0265	0.0457	0.0472
24: Hotels	0.0005	0.0000	0.0001	0.0084	0.0000	0.0107	0.0014	0.0006
25: Transport	0.0116	0.0467	0.0558	0.0225	0.0302	0.0371	0.0102	0.0094
26: Post&Com.	0.0032	0.0000	0.0068	0.0047	0.0046	0.0368	0.0046	0.0127
27: Finance	0.0297	0.0063	0.0334	0.0109	0.0071	0.0051	0.0175	0.0290
28: Real estate	0.0014	0.0000	0.0034	0.0015	0.0000	0.0001	0.0071	0.0075
29: Renting	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
30: Compt serv.	0.0018	0.0000	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000
31: R&D	0.0000	0.0005	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000
32: Other Busin.	0.0079	0.0017	0.0009	0.0259	0.0183	0.0208	0.0368	0.0487
33: Publ. Admin.	0.0023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
34: Education	0.0000	0.0000	0.0000	0.0006	0.0000	0.0010	0.0000	0.0000
35: Health	0.0000	0.0002	0.0000	0.0027	0.0000	0.0010	0.0000	0.0000
36: Other com.	0.0018	0.0036	0.0058	0.0025	0.0000	0.0064	0.0090	0.0077
37: Households	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000

Conclusions

The international comparison of construction industries is a challenging undertaking. While a variety of methods have been tried in the past, there is still little agreement on the most accurate and reliable approaches to measuring and evaluating construction activities. Comparisons are made, however, and can produce some useful insights in spite of the difficulties associated with them (Freeman, 1981; Bon and Pietroforte, 1990; Proverbs and Faniran, 2001; Pietroforte and Gregori, 2003) and 'the argument that comparisons are impossible, being beset with too many unknowns to be useful, is trite and untrue' (Flanagan *et al.*, 1986, p. 1). We have addressed the comparability issue by using the input-output framework. IO tables are useful for such analyses, as they offer detailed information on production and consumption activities in an economy by recording all the transactions between producers and consumers. The OECD dataset appears to be suited for our task since it provides useful insights about differences in construction activity over time and across countries. The study has focused on some emerging countries (BRIICS) whose standard of living differs significantly. In this regard, India is still a quite poor country, as its GDP per capita is one-tenth of that of America. In contrast, Russia is much richer, while China is quickly catching up with more developed nations. We believe that the understanding of construction's role in these economies is important.

Our analysis suggests five major conclusions. First, construction share in total final demand is larger than in value added. For instance, the 2005 final demand shares are close to 20% in China, India and Indonesia, while value added shares reach a lower value, i.e. between 5.8% and 8.7%. This confirms previous findings about highly developed nations. Construction appears to be more important in pushing economic activity or 'put differently, this indicator shows that construction and manufacturing are more productive than other sectors' (Bon, 1988, p. 60).

Second, construction share in gross output is larger than in value added in all the examined countries, except in Brazil. This is due to intermediate inputs and reflects the nature of construction operations, which involve the assembly of many different products purchased from a large number of industries. This finding, discussed at length in the literature, was expected. However, it is important to understand why Brazil is an exception. The reason is the relatively large share of primary inputs. Primary inputs (capital and labour) are important in Brazil and Russia, even if their values, about 50%, perfectly fit into the standard range found in previous research. On the other hand, China and South Africa display much smaller ratios (25%) with very strong direct backward indicators.

Our third finding concerns the structure of intermediate input provision. Manufactured goods are essential in China and, to a lesser extent, Indonesia. In earlier studies, the expenditure share in manufacturing was never equal to 55%, as in China in 1995. Other emerging markets display much smaller values that are similar to those detected in developed countries, whose shares in private services provision often are larger than those found in our sample.

The fourth finding pertains to the comparisons of data with a finer level of aggregation. In order to verify discrepancies between input vectors the cosine similarity index is introduced. This is a useful tool to match technologies and detect analogous expenditure patterns. However, some weaknesses in this approach are to be mentioned. First, vectors should be comparable and national statistical institutes should provide data in accordance with a harmonized industry structure. There are numerous imperfect concordances among sectors in the OECD dataset. Furthermore, some countries do not elaborate industry-by-industry symmetric IO tables, but make and supply matrices or commodity-by-commodity tables that often require ad hoc analysis. In our sample, the Russian construction vector in 2005 seems to be quite unreliable, and it should not be included in future studies. Some entries in other input provisions are questionable too and aggregation should be performed. Finally, we argue that a fundamental input provision structure exists. Even if countries do not share the same recipe, it is very likely that the construction industry uses a common set of inputs such as chemicals, wood, coke and refined petroleum products, basic metals, other non-metallic products, wholesale, transport, plus some private services. Further research will verify whether other countries adopt the same input mix.

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Notes

1. Bold capital letters are used for matrices, bold lower-case letters are used for vectors and italic lower-case letters for

scalars. Transposition is indicated by a prime while $\widehat{p}$ is a diagonal matrix whose entries are given by vector **p**.

2. Data available at http://goo.gl/Rt3WdH.
3. In the first half of the 1990s GDP per capita was close to \$30 000 in advanced economies such as Canada, France, Germany, Japan and to \$37 000 in the USA.
4. The difference between Pearson's correlation and Salton's cosine is geometrically equivalent to a translation of the origin to the arithmetic mean values of the vectors. Covariance and Pearson correlation are invariant to shifts (correlation to scale effects too) and are not suitable for our analysis.

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Appendix A

OECD sectoral classification

(1) Agriculture, hunting, forestry and fishing
(2) Mining and quarrying
(3) Food products, beverages and tobacco
(4) Textiles, textile products, leather and footwear
(5) Wood and products of wood and cork
(6) Pulp, paper, paper products, printing and publishing
(7) Coke, refined petroleum products and nuclear fuel
(8) Chemicals and chemical products
(9) Rubber and plastics products
(10) Other non-metallic mineral products
(11) Basic metals
(12) Fabricated metal products except machinery and equipment
(13) Machinery and equipment n.e.c
(14) Office, accounting and computing machinery
(15) Electrical machinery and apparatus n.e.c
(16) Radio, television and communication equipment
(17) Medical, precision and optical instruments
(18) Motor vehicles, trailers and semi-trailers
(19) Other transport equipment
(20) Manufacturing n.e.c; recycling
(21) Electricity, gas and water supply
(22) Construction
(23) Wholesale and retail trade; repairs
(24) Hotels and restaurants
(25) Transport and storage
(26) Post and telecommunications
(27) Finance and insurance
(28) Real estate activities
(29) Renting of machinery and equipment
(30) Computer and related activities
(31) Research and development
(32) Other Business Activities
(33) Public admin. and defence; compulsory social security
(34) Education
(35) Health and social work
(36) Other community, social and personal services
(37) Private households with employed persons