International comparisons of nominal and real construction labour productivity

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Abstract

Purpose – A comparison of international construction labour productivity (CLP) is carried out by the conventional use of exchange rates to convert national construction output to a common base currency. Such measurement is always distorted by price-level differences between countries and therefor this paper to adopts a Purchasing Power Parities (PPP) approach, which eliminates price-level differences, as an alternative means of comparing CLP.

Design/methodology/approach - PPP construction expenditure data from the World Bank's International Comparison Program 2011 and employment statistics maintained by the International Labor Organization (ILO) are used to generate the construction labour productivity (CLP) of 93 matching economies. A one-way analysis of variance (ANOVA) is conducted to evaluate the relationship between the development status and the CLPs.

Findings - The CLPs of developed economies are higher than developing economies in both PPPs (real) and exchange rate (nominal) measurements. The real CLPs are always higher than nominal CLP in high income, upper middle income, lower middle income and low-income economies. Both real and nominal CLPs converge along with the economic growth.

Research limitations/implications - The average figures used in the study may not always be the most representative statistics. The CLPs determined provide an initial approximation for comparison between different economies to gain further insights into the best practices and policies for the more successful economies. Future research is recommended to uncover the underlying factors of CLPs congruence.

Originality/value – The convergence of real and nominal CLPs when economies transit from a developing to developed status indicates the construction product has transformed from a commonly understood non-internationally traded product to an internationally traded product.

Keywords Productivity, Construction industry, International comparisons, Purchasing power parity.

Paper type: Conceptual

Introduction

Construction is an important industry because its output is large and it represents a significant part of the economy. In most countries, construction provides approximately half the gross domestic fixed capital formation (Hillebrandt 2000). The world construction industry stands at 5.7% of world Gross Domestic Product (GDP) in 2015 (United Nation Statistics Division 2017). The McKinsey Global Institute has estimated that USD10 trillion equivalent to 13% of GDP in construction-related global spending annually (Barbosa et al., 2017) and USD57 trillion worth of infrastructure investment will be required by 2030 just to keep pace with the global economy (Blanco, Janauskas and Ribeirinho, 2016). However, construction productivity has been flat for decades, it averaged only 1% a year over the past two decades, contrasted with growth of 2.8% in the world economy and 3.6% in manufacturing, according to McKinsey research (Changali, Mohammad and Nieuwland, 2015 and Barbosa et.al 2017). The overall labour productivity in Germany and Britain has risen by almost 30 percent since 1995, while their construction labour productivity in those countries is up by only approximately 7 percent over that period (Blanco et al., 2016). Productivity is the ultimate engine of growth in the economy and raising productivity is a fundamental challenge for countries going forward (OECD, 2015). While a country's productivity is the average of its industries' productivity weighted by size, Lewis (2006) suggests that a way to understand what makes countries wealthy is by evaluating the performance of individual industries. It is important to identify causes of productivity differences between companies, industries sectors and countries, and international comparisons form a crucial information base for research in comparative analysis and policymaking. However, it is difficult to price construction products that are comparable between economies because of the differences between construction industries. The complexity and country specificity of products means that no two economies build exactly the same kind of houses or power stations (The World Bank 2015). The most commonly used method for such international comparisons is to express the construction Gross Domestic Product (GDP_C) of the countries concerned in the same currency unit so that the differences in the economies are readily identifiable. Comparisons between countries are exacerbated when foreign-exchange rates are used to convert national currency.

An alternative approach is to compare GDP_C with purchasing power parity (PPP) instead of exchange rates as conversion factors (Todaro & Smith 2015). PPP is the ability of one nation's currency to purchase goods in a different nation. In other words, this compares how different currencies function in the same country, rather than trying to compare different currencies in different countries (Taillard 2013).

This research aims to investigate the difference in construction labour productivity (CLP) between PPP-based GDP_C (GDP_{C-PPP}) and exchange rate-based GDP_C (GDP_{C-XR}). The objectives are (i) to generate sets of comparable CLP for comparative analysis and (ii) to determine any relationship between CLP and the development status of economies. The following section elucidates the concepts of productivity, defines CLP, explains the different productivity measures and justifies the single factor gross output measure used here. It also highlights in more detail the problems of making international comparisons, introduces the concept of PPP and International Comparison Programs by the World Bank and summarises the PPP approach to construction expenditure by the World Bank's International Program. It. The next section provides details of the sources of data for the construction expenditure and construction employment statistics of the different economies involved, while the subsequent section presents and discusses the construction labour productivity of 93 economies computed in this study. It also compares the productivity differences between the economies based on PPPs and exchange rates. The final section concludes with the findings of the study.

Construction Labour productivity

Productivity can be a slippery concept. Tangen (2002) found many managers believed that they fully understood what productivity meant, but at the same time had difficulties in explaining the difference between productivity and such similar terms as profitability, performance, efficiency and effectiveness. If there is misunderstanding of what productivity is, how can we decide what productivity measures to use? How can they be correctly interpreted? How can we know what actions to take to improve productivity? (Tangen, 2002). Merriam-Webster defines productivity as "*the degree of effectiveness of management in utilizing the facilities for production; especially: the effectiveness in utilising labour and equipment.*" However Goenaga et.al. (2017) view the definition in an operation context and suggest a broader alternative of "*output per unit of productive effort*" in order to provide a better idea of what productivity can encompass. Ive et al. (2004) make a similar observation in that "*productivity directly relates to the ability of firms to organise production*". Naoum (2015) defines productivity as "*the maximization of output while optimizing input*". Tangen (2002) adds that "*productivity is closely connected to the use and availability of resources on one hand while strongly linked to the creation of value on the other hand*". Therefore, studies of labour productivity highlight the weaknesses and strengths of firms and industries in terms of their human capital and investment in plant and equipment per worker (Ive et al., 2004)

CLP adopted in this paper is obtained by dividing GDP_C by number in employment in the construction industry (E_C). There are several types of productivity and different hierarchical levels within productivity can be discussed (Tangen, 2002). Crawford and Vogi (2006) define average labour productivity as a single factor productivity measure that involves some measure of output (value added or gross output) by labour input (number of workers, or hours) and suggest average labour productivity can be seen as a first approximation for productivity measurement studies, with more sophisticated measures being employed for more detailed analysis of what underlies it in terms of key determinants. Ive et al. (2004) suggest that labour productivity is a function of measures of output (usually value-added) and labour inputs (either numbers engaged in construction activities, numbers of jobs, total labour hours worked or the costs of employment). The ratio between output and labour input depends to a large degree on the presence of other inputs, such as physical capital, intangible fixed assets used in production and technical and organisational change (OECD, 2016). It partially reflects the productivity of labour in terms of the personal capacities of workers or their intensity of effort and how efficiently labour is combined with other factors of production. It also reflects how many of these other inputs are available per worker and how rapidly embodied and disembodied technical change proceeds (OECD, 2001). Thus, quality of management, workforce skills, capital investment and capital intensity are all factors that determine labour productivity (Ive et al., 2004)

Martino (2015) defines labour productivity as gross value added (GVA) over the number of employees, standardized with respect to the mean of each year. Value added based labour productivity measures tend to be less sensitive to processes of substitution between materials plus services and labour than gross output-based measures. When outsourcing takes place, labour is replaced by intermediate inputs. This leads to a fall in the value added as well as a fall in labour input. The first effect raises measured labour productivity; the second effect reduces it. The growth of value added labour productivity is less dependent on changes in the ratio of intermediate inputs to labour or the degree of vertical integration (OECD, 2001). Gross output can be adopted as an alternative. Gross output measures reflects the combined effects of changes in capital inputs, intermediate inputs and overall productivity, including any direct effects of embodied or disembodied technical change. Embodied technical change enhances the production possibilities for a given set of inputs, while disembodied technical change operates through capital goods and intermediate inputs. When measured as gross output per unit of labour input, labour productivity rises because of outsourcing and falls when in-house production replaces purchases of intermediate inputs. This does not reflect a change in the individual characteristics of the workforce and a shift in technology or efficiency. The efficiency gain because of input substitution is also not captured (OECD, 2001).

Productivity is a relative concept that cannot be said to increase or decrease unless a comparison is made of variations from either competitors or other standards at a certain point of time, or of change over time (Tangen, 2002). However there are many issues involved in measuring productivity, such as lack of availability and reliability of data, failure to measure more important things (e.g. the effectiveness of project management, the quality level achieved and innovations) and difficulty in making productivity comparisons between industries (Flanagan et al., 2007).

A significant body of literature has been dedicated to research studies on CLP and related issues, and many underlying theories and industrial practices of CLP applications have been reported. However, research topics relating to CLP are highly diversified and there is a lack of systematic analysis of CLP-related issues (Yi and Chan, 2014). Ghoddousi et al. (2014), for example, found that by meeting the requirements of the framework of the theoretical model for international benchmarking of labour productivity (TMIBLP), comparisons made by TMIBLP will be accurate and the results will be reliable and in alignment with the necessities of benchmarking studies previously postulated by researchers. Ma and Liu (2014) take an econometric approach to investigating the effects of the global financial crisis on construction labour productivity. By employing the error correction model and panel regression methods, the direct and indirect effects of the financial crisis on changes in Australian construction labour productivity are explored at national and state levels. The research concludes that the influence of the late-2000s financial crisis on Australian national and state construction labour productivity is limited. In another study by Ma, Liu and Mills (2016) found that construction labour productivity in Australia should converge to stable frontiers in a long-run perspective. The productivity dynamics are mainly caused by the technology utilization efficiency levels of the local construction industry, while the influence of changes in technology level and capital dependence appear to be limited. Tsehayae and Fayek (2016) opine that CLP is affected by numerous context-sensitive influencing variables made up of subjective and objective factors, practices and work sampling proportions (WSPs) that cause complex variability. Modelling CLP is challenging because, for any given context, the complex effects of multiple variables have to be considered simultaneously without sacrificing accuracy or interpretability. The results of the investigation by Tsehayae and Fayek (2016a) show that the key variables vary between the studied contexts and context-specific models have better prediction accuracy than the generic model, and demonstrate the essential role of context in the CLP model development process using context attributes. This provides a useful approach for characterizing existing CLP models and facilitating the use and adaptation of existing CLP models in new project contexts. Moselhi and Khan (2012) provide insight into the parameters that affect daily job-site labour productivity. The three most important parameters of work types, floor level and temperature are identified in the same order among the nine parameters by fuzzy logic and neural networks methods; the regression analysis indicates that work type and floor level are common. Naoum (2016) provide a state-of-art literature review and survey of the factors influencing labour productivity on construction sites. The study revealed that, while there has been an advancement in developing techniques and tools for improving productivity on site, more needs to be done to invest in technology and innovation. The interview survey indicates factors associated with pre-construction activities to be the most critical influencing site productivity (Naoum, 2016). Vereen, Rasdorf and Hummer (2016) present a new metric for quantifying productivity using RSMeans Building Construction Cost Data. Their study results show a slightly sporadic, but consistent, productivity decline in both output per labour hour and per dollar cost from 1990 to 2008. The study supports construction professionals in analysing industry level productivity by means of a generally used and consistently published reference manual. Barbosa et al. (2017) look at the construction sector's poor historical record on productivity and performance and tested ten root causes for low construction productivity. The ten root causes include three external forces, three industry dynamics and four firm-level operational factors. Barbosa's research advocate a combination of a combination of seven-ways to improve the construction sector's productivity by 50 to 60%. The seven ways are (1) reshape regulation and raise transparency, (2) rewire the contractual framework, (3)rethink design and engineering processes, (4) improve procurement and supply-chain management, (5) improve on-site execution, (6) infuse digital technology, new materials, and advanced automation and (7) reskill the workforce (Barbosa et al., 2017).

International comparisons

Compared with the main internationally-traded sectors, productivity-level comparisons for construction are harder to do because of the exceptional difficulties in both output and input measurement, and the problems of finding appropriate rates of conversion to common purchasing-power units are increased by the heterogeneity of construction output and complexity of national differences in output mix and quality (Ive et al., 2004). The main problem with international comparisons is the heterogeneous nature of the construction output. Such heterogeneous output causes the use of aggregate quantity measures of construction to be infeasible, leaving the use using monetary values as the only option (Meikle & Gruneberg 2015). Nominal construction output expressed in national currency is then converted to a common currency, such as USD, with the market exchange rate used to make comparisons. The exchange rate, however, does not provide construction outputs valued at a common price level and does not reflect the relative purchasing power of currencies in their national markets, so expenditure is still valued at national price levels. Comparisons will be possible if all goods and services are traded internationally, and the supply and demand for currencies are predominantly driven by the currency requirements of international trade (The World Bank 2015). However, for many goods and services, such as buildings, government services and most household market services are not traded internationally, and thus they are valued at domestic market prices (The World Bank 2015).

Moreover, the supply and demand of currencies are influenced by many factors such as currency speculation, interest rates, government intervention and capital flows between economies. Hence, the volatility of exchange rates often distorts a country's construction costs making it difficult to compare with the cost of construction in other countries (Meikle & Gruneberg, 2015). In order to compare trends over time, appropriate deflators are required and purchasing power parties are used rather than exchange rates in order to compare the levels in different countries (Ive et al., 2004).

Converting nominal expenditure to real expenditure by PPP will remove the impact of exchange rate volatility (Turner and Townsend 2015). Real expenditure valued at a common price level reflects real or actual differences in the volume purchased in economies and provides the measures required for international volume comparisons (The World Bank 2015).The International Comparison Program (ICP) conducted under the charter of the United Nations Statistical Commission (UNSC) published national accounts in PPPs. The latest round of the ICP 2011, in which 199 economies participated, provides a full set of results for 177 economies, which accounts for around 97% of the world's population and 99% of the world nominal GDP.

The next two sub sections introducing the PPP methodology and PPP of construction expenditure are, unless otherwise referenced, mostly drawn from The World Bank's (2015) *Purchasing Power Parities and the Real Size of World Economies: A Comprehensive Report of the 2011 International Comparison Program,* Washington.

Purchasing power parity

PPP is defined as a spatial price deflator and currency converter. It includes a two-component ratio as expressed in the following equation (1).

$$\text{PPP} = \text{price level ratio x currency ratio} \quad (1)$$

However, there are three component ratios when the GDP ratio of two economies are valued at national price levels and expressed in national currencies:

$$\text{GDP ratio} = \text{price level ratio x volume ratio x currency ratio} \quad (2)$$

Before PPPs became widely available, exchange rates were used to convert GDPs to a common currency in order to make international comparisons of GDP. Exchange rate-converted GDP or nominal GDP (GDP_{XR}) reflects both the price level differences and volume differences between the two economies.

$$GDP_{XR} = \text{price level ratio x volume ratio} \quad (3)$$

When PPP is used, the GDP ratio in (2) is divided by (1), and the resulting real GDP (GDP_{PPP}), ratio has only one component ratio

$$GDP_{PPP} \text{ ratio} = \text{volume ratio} \quad (4)$$

Therefore, the real GDP ratio in (4) is expressed in a common currency that is valued at a common price level and reflects only the volume differences between the two economies. They take into account the different price levels for traded products and nontraded products. They are price relatives that show the ratio of the prices in national currencies of the same good or service in different economies.

Purchasing power parity of construction expenditure

Construction expenditure is one of the 25 sub aggregates of expenditure reported in ICP 2011. It includes capital expenditure on the construction of new structures and renovation of existing structures. Gross fixed capital formation in construction is broken down into three basic headings: residential buildings, non-residential buildings and civil engineering works. The complexity and the country specificity of the products of the construction industry mean that the products are unique. It is therefore difficult to price construction products that are comparable between economies. One way of overcoming this difficulty is for economies to price a common set of standard construction projects covering different types of buildings and civil engineering works.

The bill of quantities approach was used in the Eurostat-OECD comparison. This method required all economies to price the bill of quantities of a common set of fictitious standard buildings and civil engineering projects based on the actual structures, materials and methods commonly used in their construction. Each economy was expected to price 7 out of 11 standard construction projects using the prices of successful tenders submitted during the reference year. The price included the contractor's mark-ups for general site costs, head office overheads, profit and the cost of employing professional architects and engineers. The PPPs for construction are calculated using the overall prices of the projects.

A modified version of the bill of quantities approach was applied in the Commonwealth of Independent States (CIS) economies. In order to price simpler and less complete bills of quantities of an extensive range of model structures, the economies were asked to provide unit prices for 66 inputs, covering materials and labour for the regional coordinating agency. The PPPs for construction were calculated using the overall prices for the model structures.

Other participating economies followed the approach developed by the Global Office for ICP 2011. The economies were required to collect unit prices for 38 different building materials, the hourly cost of hiring five types of building equipment with and without an operator. The economies were also asked to include the hourly rate at which compensation was paid to construction workers across 7 occupations and for a common set of 55 inputs. In addition, the national coordinators were asked to indicate the type of structures for which each of the inputs was commonly used and the average resource mix for each of the three basic headings. PPPs for the basic headings were obtained by aggregating the PPPs of their subheadings with subheading expenditure weights.

Research methods

Construction labour productivity (CLP) adopted in this study is the single factor productivity ratio of gross construction output to labour input. The PPP-deflated or real construction expenditure published in ICP 2011 is used as the proxy for gross construction output. The PPP-deflated or real expenditures are expressed in a common currency unit and are valued at the same price level. The expenditure approach in ICP comparisons allows comparison of the levels of final demand in consumption and investment, which avoids the effect of double deflation. Its disadvantage is that productivity comparisons can only be made at the level of the whole economy (The World Bank 2015). Breton (2015) criticises ICP 2011 construction prices being substantially underestimated in most of the low and middle-income countries. However, Deaton and Aten (2017) conclude that "*ICP2011 estimates are the most accurate that we have, and provide no grounds for doubting them*", alerting that, for international studies, local real growth rates will often be as, or more, relevant than growth rates in international dollars. When common units are required, within-region work is likely to be more accurate because PPPs within each region are calculated without reference to prices and expenditure patterns in countries outside the region (Deaton and Aten, 2017).The quantity of labour input is obtained from the International Labor Organization's central statistics database (ILOSTAT) which is the primary source for cross-country statistics on the labour market. ILOSTAT provides up-to-date labour data for over 100 indicators and 165 economies. Employment by construction of economies are extracted from the section of *Employment by Economic Activity and Occupation* of the database, which are used as proxies of quantity of labour input (ILO 2015)

There are 93 matching pairs of economies found in the employment statistics of ILOSTAT and construction expenditure in ICP 2011. They account to 82.5% and 89.9% of construction expenditure based on PPP and exchange rates respectively. The construction labour productivities of these 93 economies are computed and reported in Appendix I. Real construction expenditure is based on PPP whereas nominal construction expenditure is based on exchange rates. The construction labour productivity of different economies needs to be expressed in the same currency unit so that the differences in productive levels of different economies are readily identifiable. Therefore, each economy's construction labour productivity has been standardized by dividing it by that economy's dollar exchange rate.

The Construction Labor Productivity Indexes (CLPIs) included in the Appendix 1 are standardised indices expressed by the construction labour productivity of an economy relative to the world average productivity level, which is set at 100. Economies with CLPIs greater than 100 have construction labour productivity levels that are higher than that of the world average. Economies with CLPIs less than 100 have construction labour productivity levels that are lower than that of the base economy.

The most common way to define the developing world is by per capita income. Several international agencies, including the Organization for Economic Cooperation and Development (OECD) and the United Nations, offer classifications of countries by their economic status, but the best-known system is that of the International Bank for Reconstruction and Development (IBRD), more commonly known as the World Bank (Todaro and Smith, 2015). . The World

Bank classifies economies based on estimates of gross national income (GNI) per capita for the previous year. As of 1 July 2011, low-income economies (LI) are those that had average 2010 incomes per capita of not more than $1005; lower-middle-income economies (LMI) had average incomes of $1006 to $3975; upper-middle-income (UMI) economies had average incomes of $3976 to $12 275; and high-income (HI) had average incomes of $12 276 or more. Low and middle-income economies are commonly referred to as developing economies (World Bank 2011).

Results

Figure 1 is a boxplot of the CLPs of the 93 economies, which indicates the CLP of Bhutan to be an outlier. Figure 2 is the boxplot of CLPs grouped by developing status and shows there are five outliers, two (Aruba and Macao) in HI economies, two (China and Seychelles) in UMI economies, and one (Bhutan) in LMI economies. Therefore, these five economies are excluded from the subsequent analysis.

Insert Figure 1 here.

Insert Figure 2 here.

The median CLPs of the four groups of economies descend from HI economies to LI economies. The right hand long "tails" of the CLP distributions of HI and LMI economies are positively skewed. The interquartile ranges of HI and LMI economies also show greater within-group variation than the others. The disparate sample size suggests a potential problem with the homogeneity of variance assumption i.e. that all groups have the same or similar variance. The homogeneity assumption is tested by the Levene test of homogeneity. The significant result for both real and nominal CLPs presented in Table 1 indicates the assumptions of equal variance to be violated. Consequently, the Games-Howell test, designed for such a situation, is adopted for the *post hoc* test.

Insert Table 1 here.

A paired sample t test indicates that real CLP is significantly higher than nominal CLP, d=0.83, t_{87}=7.76, p=0.00. The difference is much larger than typical suing Cohen's (1988) guidelines.

Insert Table 2 here.

Table 3 shows the real CLPs to be significantly different from nominal CLPs in the HI (p=0.001), UMI (p=0.000) and LMI economies (p=0.002); but not the LI economies (p=0.356). All the real CLPs are higher than the nominal CLPs. The effect size d, the quantitative measure of the strength of a phenomenon, is 0.537 for HI economies, which is a typical effect according to Cohen (1988). However, the effective sizes of 2.498 and 0.982 for the UMI and LMI economies respectively indicate much larger than typical effect according to Cohen (1988).

Insert Table 3 here.

A one-way analysis of variance (ANOVA) was conducted to evaluate the relationship between the development status (independent variables) and the CLPs (dependent variables). Table 4 shows that the evaluation result of real CLP and development status is significant, $F_{(3, 84)}$=20.43, p=0.00. The strength of relationship between the variables, as assessed by η^2, is 0.42, which indicates the development status accounting for 42% of the variance of the CLP. A similar significant result is obtained in the relationship between nominal CLP and development status, $F_{(3, 84)}$=24.71, p=0.00. The strength of relationship between the variables, as assessed by η^2, is 0.47, which indicates the development status accounting for a higher variance of the nominal CLP (47%) compared with the real CLP (42%).

Insert Tables 4 here.

Since the overall F is significant and the assumptions of equal variance are violated as presented in Table 1, the Games-Howell test, designed for situations in which the variances are unequal, is adopted for post hoc test. There are significant differences in the average real CLP between the HI and all other levels of income groups, but not between the inter group comparisons. The paired differences (I-J) between HI and UMI, HI and LMI, and HI and LI economies are 52 000 (p=0.00), 83 044 (p=0.00) and 96 899 (p=0.01) respectively (Table 4).

However, in the case of nominal CLPs, significant differences are detected in all pairs of inter group comparisons except for the pair between the LMI and LI economies. The pair differences (I-J) between HI and UMI, HI and LMI, and HI and LI are 74 921 (p=0.00), 89 864 (p=0.00), and 98 717 (p=0.00) respectively. The paired differences (I-J) between UMI and LMI, and UMI and LI are 14 944 (p=0.00) and 23 796 (p=0.00) respectively (Table 5).

Insert Tables 5 here.

The Brown-Forsythe and Welch tests are used, which test for equality of group means without assuming homogeneity of variance. Both of these measures mathematically attempt to adjust for the lack of homogeneity of variance. When calculating the between group to within-group variance ratio, the Brown-Forsythe test explicitly adjusts for heterogeneity of variance by adjusting each group's contribution to the between-group variation by a weight related to its within-group variation. The Welch test adjusts the denominator of the F ratio so it has the same expectation as the numerator when the assumption of homogeneity of variance is violated (Field, 2013).

Both tests indicate there are highly significant differences in both average real CLPs and average nominal CLPs among the development status groups (Table 5), which are consistent with the conclusions we drew from the standard ANOVA.

Insert Table 6 here.

Table 7 indicates that real CLP and real expenditure per capital are significantly correlated, similarly for nominal CLP and nominal expenditure per capita. However, the correlations of the nominal pair of variables (r = .821) are relatively much stronger than the real pair of variables (r = .552).

Insert Table 7 here.

Table 8 summarises the above findings. Most of the differences between the variables tested are statistically significant with the exceptions of: real CLP and nominal CLP in low-income economies, real CLPs between upper middle-income and lower middle-income economies, real CLPs between lower middle-income and low-income economies and nominal CLPs between lower middle-income and low-income economies. In conclusion, the differences of CLPs are more significantly different when measured with exchange rates and relatively less significant with purchasing power parity measurement. The real CLP shown significant differences only when high income economies are compared with those in the lower income economies and not in the comparisons between other grouping of economies.

Insert Table 8 here

CLP appears to be higher in high-income economies and lower in low-income economies regardless of real or nominal measurement. Real CLPs are higher than nominal CLPs in all the four levels of income groups. The differences between real and nominal CLPs are greater in the low-income economies than the high-income economies. Table 9 shows the ratio of real CLP to nominal CLP starts at 4.7 in low-income economies, decreases to 3.0 and 2.6 in lower middle and upper middle-income economies respectively, and finally narrows to 1.3 in high-income economies. In short, as the economies are growing from low income to high-income development status, the differences between real and nominal CLPs are decreasing.

Insert Table 9 here.

Discussion

Relatively higher CLPs are achieved in the higher income economies regardless of whether they are based on PPPs or exchange rates. Eight of the top ten economies with the highest construction expenditure (listed in Appendix 1) are HI economies. The two exceptions based on PPPs are Indonesia (LMI) and Mexico (UMI). However if based on exchange rate, the two exceptional economies are China (UMI) and Indonesia (LMI). All the nine outperformers (high productivity, positive productivity growth) identified by Barbosa et al. (2017) in their study of construction labour-productivity growth, 1995-2015 are from HI economies. These nine outperformers are Australia, Belgium, Canada, Denmark, Germany, Israel, Netherland, Sweden and United Kingdom. Among these nine economies, Belgium and Israel construction sector productivity growth exceeds their total economy, while the other seven economies sector productivity growth lag behind total economy (Barbosa, 2017).

Nine of the top ten international construction in ENR (2016) are from HI economies, except for the third largest, China Communication Construction Group is from UMI economies. The enormous construction projects such as USD64 million Dubailand, Yavuz Sultan Selim intercontinental bridges, Gotthard Base Tunnels and Panama Canal Expansion project tip the scales on size, complexity and cost. The complexities of these projects require novel inputs. Ive et al. (2004) advocate construction industry productivity improvements closely related to opportunities to innovate provided by project design decisions that are outside the control of construction firms (Ive et al., 2004). In addition, larger firms have a lower porosity of the working day, higher work intensity or greater non-capital-embodied efficiency; and for the larger firms there is an implied bargain that workers will work with above average intensity and will receive above average wages in return (Gruneberg and Ive 2000). Furthermore, the substitution of labour with capital will result with a relatively higher average labour productivity. What is being measured, however, are differences in firms' capital intensity and not differences in performance (Crowford and Vogi, 2006).

The relatively less significant differences of PPP-measured than exchange rates-measured CLPs support the World Bank (2015) explanation that many goods and services, which include buildings, are not traded internationally. This observation is coincided especially when comparisons are done among the lower income economy groups, such as between LMI and LI.

However, real CLPs are higher than the nominal CLPs in all the income groups and the gap between real and nominal CLPs narrowed as the economies are growing from low income to high-income development status, indicating a convergence between real and nominal CLPs with changing economic status. This is consistent with neoclassical growth theory, which establishes a presumption that countries that are poorer and have higher marginal productivity of capital should grow more rapidly in the transition to the long-run steady state (Rodrik, 2013). In an open global economy, access to foreign capital and foreign markets (which removes finance and market size as constraints) further strengthens the presumption of convergence (Rodrik, 2013). Ma, Liu and Mills (2016) found similar a convergence of construction labour productivity across regions and over time in Australia, concluding that the productivity dynamics involved are mainly caused by the technology utilisation efficiency levels of the local construction industry. With the globalization of the world economy, today's construction business is fast becoming an internationally independent marketplace. According to ENR (2016), the Top 250 International Contractors obtained USD 521.55 billion in contracting revenue in 2014 from projects outside their home countries, which represents an almost three-fold increase over the USD 189.4 billion recorded in the last ICP 2005. In addition, with the rise of modern industrialized countries, increasingly complex civil engineering projects are being procured, and the increased scale of these projects has provided a launching pad for international construction. Advanced technology, fast transportation, convenient communications, effective knowledge transfer, integrated markets and trade liberalization have all helped to lower traditional barriers and transform construction into a fiercely competitive international marketplace where the fortunes of construction companies ebb and flow (Lu, et al. 2015). Economic development is generally unidirectional, that is, each country must go through the development process from least developed to developed stages. As an economy is growing into a more developed status, more complex and complicated projects are undertaken that will involve advanced construction technology, construction materials, foreign specialists etc. Comparison of the CLP of ICP2005 and ICP2011 in Table 9 also reveals that the average CLPs of all groupings of economies had improved with the only exception being the low-income economies. Gruneberg and Ive (2000) observe that the high wage and high productivity sector of the economy may be able to concentrate most of the available supply of investment capital precisely because the low wage and low productivity sector has low capital investment requirements, yet can absorb all the increase in the national total labour force (Gruneberg and Ive, 2000). Over time, technical change makes more capital-intensive methods profitable, and this in itself favours those firms able to command larger amounts of capital (Gruneberg and Ive 2000). Rodrik (2013) found countries with access to identical technologies should converge to a common income level. Martino (2015) added the convergence does not need to apply to the economy as a whole, but can still take place in some specific modern sectors particularly suited to the flow and adoption of innovative activities.

Conclusions

The problem of making comparisons between labour productivity at industry and national levels is attributable to the difficulty of distinguishing the contributory effects of labour from other factors (Ghoddousi et al., 2017). CLP based on PPPs are significantly higher than CLPs based on exchange rates. PPPs-converted CLPs reflect only differences in the volumes produced by the economies. PPPs take into account the different price levels for traded products and nontraded products and show the ratio of the prices in national currencies of the same good or service in different economies.

Construction labour productivity tends to be higher in high-income economies than low-income economies regardless of whether it is being measured by PPPs or exchange rates. In high-income economies, the nature of the projects and the availability of capital resources allow for more machine-for-labour substitution in construction projects.

The construction labour productivity measures of the two methods tend towards convergence as the economies grow from a developing to developed status. A possible explanation is that construction labour productivity in low-income economies is understated. Another explanation is that market exchange rates will eventually have a more influential role because the construction industry is changing from being a long-established non-international traded industry to a more complex international traded industry. If this is the case, the role of international contracting is going to change the productivity of the construction industry. Construction projects have increased both in their complexity and scale and there are increasing numbers of construction contracts being won by international contractors. Advanced construction technology, newly developed construction materials, integrated project delivery and trade liberalization are removing the traditional barriers of construction markets, driving their transformation into a fiercely competitive international marketplace.

The data used in this paper mainly comprises average or mean figures. These averages necessarily conceal evidence of variation of single cases about the mean. The mean and median of the distribution of a variable may not always be the most representative or characteristic statistics (Gruneberg and Ive 2000). As the deployment of technology becomes increasingly intertwined with the employment of human resources, what we compare will be the result of the combined effects of that engagement between workers and tools, not merely the outcome of labour taken in isolation (Flanagan et al. 2007). Hence, the single factor measure such as labour productivity may not be well suited to the analysis of total productivity performance. The performance measurement needs to distinguish between total and partial economic efficiency in production (Crowford and Vogi, 2006). Nevertheless, the use of national industrial averages is certainly worthwhile in analysing national industrial temporal changes.

The two implications of this study are that, firstly, it benchmarks the construction labour productivity based on the PPPs of 93 economies, which provides an initial comparison of the volume of output between the economies. The approximate relative construction productivity of an economy will be useful for policy makers and researchers in evaluating the effectiveness of the industrial practices and policies. Secondly, the convergence of construction labour productivity and total economic growth of some economies indicates needs to further gain insights on the causes of the phenomenon. Thirdly, the underlying determinants of more successful economies need to be uncovered so that the applicable best practices and lessons learned can be shared by the construction industry globally.

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Table 1. Test of homogeneity of variance of real CLP and nominal CLP

	Levene statistic	df1	df2	Sig
Real CLP	4.360	3	84	.007
Nominal CLP	49.740	3	84	.000

Table 2. Comparison of real and nominal CLPs (n = 88)

Variable	M	SD	t	df	sig	d
Real CLP	102 795	53 497	7.757	87	.000	.827
Nominal CLP	68 534	60 300				

Table 3. Comparison of real and nominal CLP on development status

Developing status	N	M	SD	t	df	sig	d
High income							
Real CLP	47	133 334	47 745	3.679	46	.001	.537
Nominal CLP	47	106 529	59 714				
Upper middle income							
Real CLP	24	81 335	25 588	12.239	23	.000	2.498
Nominal CLP	24	31 608	10 578				
Lower middle income							
Real CLP	15	50 290	40 772	3.805	14	.002	.982
Nominal CLP	15	16 664	10 100				
Low income							
Real CLP	2	36 435	27 328	1.598	1	.356	1.130
Nominal CLP	2	7 812	1 999				

Table 4. One-way analysis of variance of real and nominal CLPs on comparing developing status

Developing status	Real CLP						Nominal CLP					
	Sum of squares	df	Mean square	F	Sig	Partial η^2	Sum of squares	df	Mean square	F	Sig	Partial η^2
Between groups	105 046 285 722	3	35 015 428 574	20.434	.000	.422	148 305 307 835	3	49 435 102 611	24.713	.000	.469
Within groups	143 937 784 845	84	1 713 545 058				168 029 397 656	84	2 000 349 972			
Total	248 984 070 568	87					316 334 705 492	87				

Table 5. Post hoc tests of real and nominal CLPs across developing status

(I) Developing status	(J) Developing status	Real CLP					Nominal CLP				
		Mean difference (I-J)	Std. error	Sig.	95% Confidence interval		Mean difference (I-J)	Std. error	Sig.	95% Confidence interval	
					Lower bound	Upper bound				Lower bound	Upper bound
High income	Upper middle income	52000*	10385	.000	24777	79222	74921*	8974	.000	51095	98747
	Lower middle income	83044*	12276	.000	50867	115221	89864*	9092	.000	65751	113978
	Low Income	96899*	29887	.009	18559	175239	98717*	8824	.000	75214	122220
Upper middle income	High income	-52000*	10385	.000	-79222	-24777	-74921*	8974	.000	-98747	-51095
	Lower middle income	31044	13626	.111	-4669	66758	14944*	3386	.001	5755	24134
	Low income	44900	30466	.458	-34958	124757	23796*	2581	.000	15737	31856
Lower middle income	High income	-83044*	12276	.000	-115221	-50867	-89864*	9092	.000	-113978	-65751
	Upper middle income	-31044	13625	.111	-66758	4669	-14944*	3386	.001	-24134	-5754
	Low income	13855	31161	.970	-67824	95535	8853	2966	.054	-128	17833
Low income	High income	-96899*	29887	.009	-175239	-18559	-98717*	8824	.000	-122220	-75214
	Upper middle income	-44900	30466	.458	-124757	34958	-23796*	2581	.000	-31856	-15737
	Lower middle income	-13855	31161	.970	-95535	67824	-8853	2966	.054	-17833	128

* The mean difference is significant at the .05 level

Table 6. Robust tests of equality of means

Tests	Real CLP				Nominal CLP			
	Statistics	df1	df2	Sig	Statistics	df1	df2	Sig
Welch	16.665	3	5.010	.005	60.059	3	17.946	.000
Brown-Forsythe	28.803	3	18.923	.000	80.988	3	55.141	.000

Table 7. Correlation of real and nominal CLP, and real and nominal expenditure per capita (N = 88)

	Real CLP	Nominal CLP
Real expenditure per capita	.552**	.570**
Nominal expenditure per capita	.604**	.821**

** Correlation is significant at the 0.01 level (2-tailed)

Table 8. Summary of statistical findings

Differences between	Statistical Findings
CLP_{PPP} and CLP_{XR}	Significant
CLP_{PPP-HI} and CLP_{XR-HI}	Significant
$CLP_{PPP-UMI}$ and CLP_{XR-UMI}	Significant
$CLP_{PPP-LMI}$ and CLP_{XR-LMI}	Significant
CLP_{PPP-LI} and CLP_{XR-LI}	Not significant
CLP_{PPP} and developing status	Significant
CLP_{XR} and developing status	Significant
CLP_{PPP-HI} and $CLP_{PPP-UMI}$	Significant
CLP_{PPP-HI} and $CLP_{PPP-LMI}$	Significant
CLP_{PPP-HI} and CLP_{PPP-LI}	Significant
$CLP_{PPP-UMI}$ and $CLP_{PPP-LMI}$	Not significant
$CLP_{PPP-UMI}$ and CLP_{PPP-LI}	Not significant
$CLP_{PPP-LMI}$ and CLP_{PPP-LI}	Not significant
CLP_{XR-HI} and CLP_{XR-UMI}	Significant
CLP_{XR-HI} and CLP_{XR-LMI}	Significant
CLP_{XR-HI} and CLP_{XR-LI}	Significant
CLP_{XR-UMI} and CLP_{XR-LMI}	Significant
CLP_{XR-UMI} and CLP_{XR-LI}	Significant
CLP_{XR-LMI} and CLP_{XR-LI}	Not significant

CLP_{PPP} – real CLP; CLP_{XR}- nominal CLP, HI – high income economies, UMI – upper middle income economies, LMI - lower middle income economies, LI – low income economies

Table 9. CLP of the ICP2005 and ICP2011 group according to economic development status

Development Status	ICP2005			ICP2011			Changes of ICP2011	
	Real	Nominal	Real/ Nominal	Real	Nominal	Real/ Nominal	Real	Nominal
High income economies	102,898	99,298	1.04	133,334	106,528	1.25	30%	7%
Upper middle income economies	42,091	19,291	2.18	81,335	31,608	2.57	93%	64%
Lower middle income economies	35,923	11,207	3.21	50,290	16,664	3.02	40%	49%
Low income economies	55,415	14,416	3.84	36,435	7,812	4.66	-34%	-46%

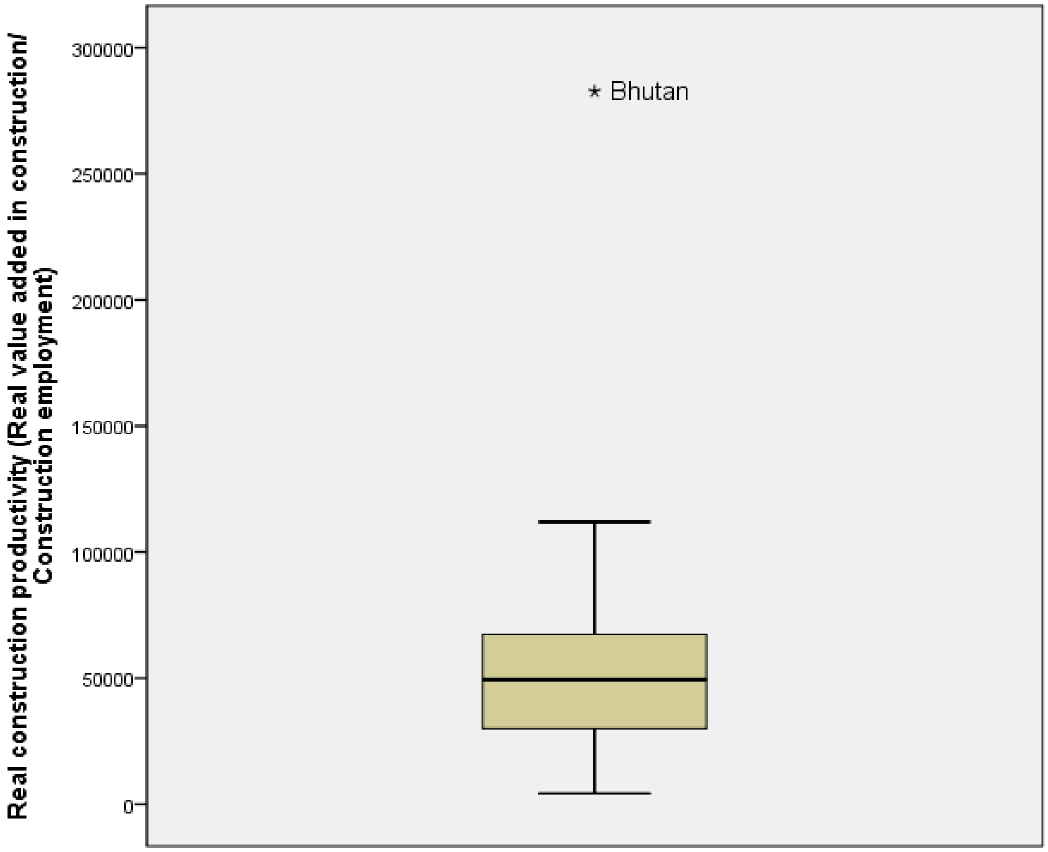

Fig. 1. Boxplot of CLP based on PPP (USD ‘000/construction employment)

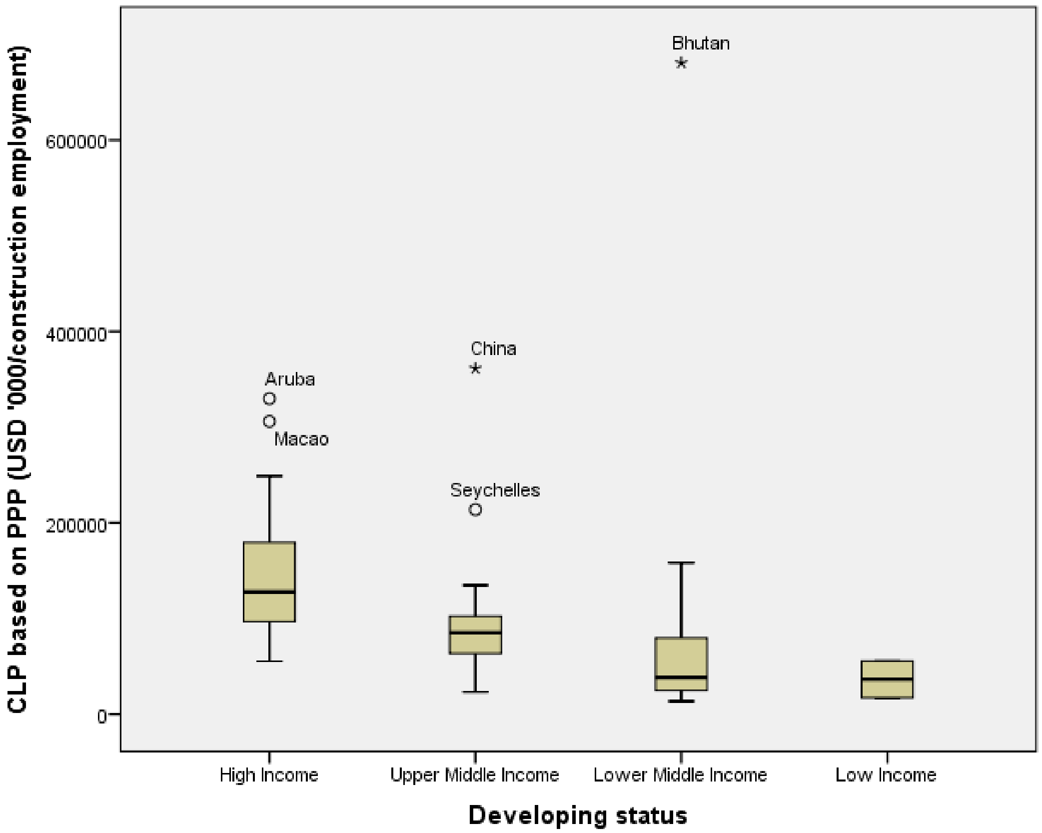

Fig. 2. Boxplot of CLP based on PPP (USD ‘000/construction employment) and developing status

Appendix 1: Real and Nominal Construction Labour Productivity, 2011

	Expenditure in construction		Construction	Real construction labour productivity		Nominal construction labour productivity	
	Real (USD, billions)	Nominal (USD, billions)	employment ('000 person)	USD / employment	Index (World = 100)	USD / employment	Index (World = 100)
Singapore	86.53	37.15	99.7	867,863	678.20	372,628	481.52
Bhutan	3.06	0.72	4.5	680,664	531.91	159,595	206.23
Luxembourg	7.14	6.11	14.5	492,639	384.98	421,138	544.21
China	6,230.30	2,106.30	17,248.0	361,219	282.28	122,119	157.81
Aruba	1.38	0.51	4.2	329,689	257.64	122,314	158.06
Macao SAR	8.66	3.47	28.3	305,957	239.09	122,469	158.26
Saudi Arabia	322.04	75.24	1,293.7	248,933	194.53	58,159	75.15
Seychelles	0.45	0.20	2.1	213,840	167.11	93,528	120.86
Belgium	69.58	57.01	337.5	206,154	161.10	168,909	218.27
Netherlands	87.62	84.03	438.1	199,997	156.29	191,795	247.84
Finland	35.24	34.27	176.2	199,983	156.28	194,469	251.30
Canada	249.44	276.70	1,294.6	192,678	150.57	213,732	276.19
Hong Kong SAR	53.32	27.49	277.0	192,501	150.43	99,243	128.25
Ireland	20.39	12.90	107.8	189,143	147.81	119,622	154.58
Israel	29.87	25.52	162.5	183,807	143.64	157,050	202.95
France	338.44	345.93	1,885.4	179,506	140.28	183,479	237.10
Denmark	27.04	29.35	159.5	169,527	132.48	184,002	237.77
Spain	235.13	154.33	1,403.9	167,482	130.88	109,929	142.05
Norway	31.31	45.54	189.9	164,883	128.85	239,836	309.93
Cayman Islands	0.51	0.36	3.2	159,829	124.90	113,749	146.99
Korea, Rep.	277.83	173.92	1,750.7	158,699	124.02	99,343	128.37

	Expenditure in construction		Construction	Real construction labour productivity		Nominal construction labour productivity	
	Real (USD, billions)	Nominal (USD, billions)	employment ('000 person)	USD / employment	Index (World = 100)	USD / employment	Index (World = 100)
Indonesia	1,001.74	219.34	6,324.5	158,391	123.78	34,681	44.82
Italy	276.43	199.64	1,791.2	154,327	120.60	111,454	144.02
Switzerland	41.83	61.51	274.0	152,675	119.31	224,479	290.08
Taiwan, China	122.92	44.02	830.6	147,983	115.64	53,002	68.49
United States	1,295.00	1,295.00	9,039.0	143,268	111.96	143,268	185.14
Romania	85.11	29.94	631.3	134,817	105.35	47,420	61.28
Germany	342.56	366.08	2,576.8	132,940	103.89	142,067	183.58
Bahamas, The	1.85	1.06	14.3	129,530	101.22	73,778	95.34
Albania	9.28	3.21	72.4	128,236	100.21	44,298	57.24
Slovenia	6.93	4.64	54.2	127,832	99.90	85,667	110.70
Australia	129.03	230.80	1,013.9	127,261	99.45	227,640	294.16
Austria	45.02	45.82	354.2	127,117	99.34	129,373	167.18
Croatia	14.91	7.08	117.9	126,460	98.82	60,071	77.63
Greece	30.45	23.12	245.8	123,895	96.82	94,053	121.54
Portugal	51.59	26.28	423.1	121,938	95.29	62,106	80.26
Malta	1.31	0.71	11.6	113,118	88.40	60,882	78.67
Mongolia	5.83	1.72	52.0	112,181	87.67	33,156	42.84
Sweden	34.24	48.78	309.5	110,622	86.45	157,615	203.68
United Kingdom	231.45	202.31	2,202.1	105,104	82.13	91,871	118.72
Mauritius	5.62	1.77	54.1	103,792	81.11	32,666	42.21
Montenegro	1.21	0.55	11.7	103,673	81.02	47,336	61.17
Turkey	171.27	70.15	1,674.5	102,283	79.93	41,891	54.13
Macedonia, FYR	4.06	1.33	40.0	101,554	79.36	33,361	43.11
Lithuania	8.57	4.56	85.1	100,747	78.73	53,577	69.23
Serbia	11.62	4.15	118.7	97,928	76.53	34,941	45.15

	Expenditure in construction		Construction	Real construction labour productivity		Nominal construction labour productivity	
	Real (USD, billions)	Nominal (USD, billions)	employment ('000 person)	USD / employment	Index (World = 100)	USD / employment	Index (World = 100)
Latvia	5.94	3.33	60.9	97,609	76.28	54,657	70.63
Hungary	25.20	12.84	260.1	96,892	75.72	49,355	63.78
Czech Republic	41.69	26.12	431.0	96,723	75.59	60,597	78.31
Cyprus	4.38	2.75	45.9	95,358	74.52	59,846	77.33
Malaysia	105.90	32.14	1,133.6	93,417	73.00	28,351	36.64
South Africa	95.27	36.50	1,054.5	90,342	70.60	34,611	44.73
Colombia	102.17	48.85	1,144.7	89,253	69.75	42,678	55.15
Mexico	329.68	171.10	3,716.8	88,701	69.32	46,035	59.49
Chile	54.06	29.92	620.3	87,150	68.10	48,239	62.34
Uruguay	10.47	5.46	120.3	87,055	68.03	45,405	58.67
Iceland	0.87	1.07	10.0	86,830	67.85	107,394	138.78
Japan	432.53	571.96	5,020.0	86,161	67.33	113,936	147.23
Estonia	5.02	2.69	58.9	85,278	66.64	45,591	58.91
Sri Lanka	42.41	10.12	508.5	83,397	65.17	19,897	25.71
Venezuela, RB	90.96	28.65	1,117.7	81,385	63.60	25,636	33.13
Peru	69.30	28.57	866.2	80,006	62.52	32,980	42.62
Tunisia	35.23	6.33	441.7	79,765	62.33	14,320	18.51
Costa Rica	9.50	4.38	123.8	76,702	59.94	35,380	45.72
Morocco	80.47	15.73	1,059.0	75,983	59.38	14,853	19.19
Poland	96.20	58.54	1,278.9	75,223	58.78	45,771	59.15
New Zealand	12.83	16.85	172.0	74,616	58.31	97,956	126.58
Bulgaria	16.02	6.13	228.7	70,051	54.74	26,798	34.63
Dominican Republic	16.30	6.35	244.2	66,760	52.17	25,997	33.59
Slovakia	16.02	10.01	241.0	66,477	51.95	41,546	53.69

	Expenditure in construction		Construction employment ('000 person)	Real construction labour productivity		Nominal construction labour productivity	
	Real (USD, billions)	Nominal (USD, billions)		USD / employment	Index (World = 100)	USD / employment	Index (World = 100)
Thailand	137.65	30.67	2,173.4	63,334	49.49	14,110	18.23
Qatar	31.02	7.84	497.5	62,358	48.73	15,754	20.36
Panama	9.73	4.47	162.0	60,070	46.94	27,578	35.64
Algeria	105.13	32.95	1,791.0	58,700	45.87	18,399	23.78
Brazil	458.22	197.74	7,814.4	58,637	45.82	25,305	32.70
Kazakhstan	34.67	25.63	614.0	56,466	44.13	41,736	53.93
Ethiopia	21.22	3.51	380.6	55,759	43.57	9,225	11.92
Russian Federation	282.83	221.08	5,106.4	55,387	43.28	43,294	55.95
Belarus	20.77	11.13	400.8	51,831	40.50	27,774	35.89
Ecuador	19.08	5.90	382.4	49,904	39.00	15,420	19.93
Senegal	5.98	2.08	131.6	45,437	35.51	15,806	20.42
Philippines	90.82	20.88	2,091.0	43,435	33.94	9,987	12.91
Guatemala	10.40	3.33	265.4	39,195	30.63	12,554	16.22
Armenia	2.52	2.13	67.4	37,377	29.21	31,598	40.83
Egypt	83.66	19.52	2,716.0	30,802	24.07	7,186	9.29
Paraguay	5.98	2.04	199.0	30,065	23.49	10,264	13.26
Georgia	1.94	1.57	65.2	29,674	23.19	24,015	31.03
Azerbaijan	7.12	5.83	308.9	23,059	18.02	18,869	24.38
Ukraine	26.24	18.03	1,311.9	20,002	15.63	13,742	17.76
Moldova	1.21	0.99	66.8	18,098	14.14	14,770	19.09
Zimbabwe	1.74	0.65	101.8	17,111	13.37	6,398	8.27
Pakistan	73.50	13.74	4,414.5	16,650	13.01	3,113	4.02
Bolivia	5.38	1.71	393.5	13,667	10.68	4,340	5.61

Source: Computed from ICP 2011 and employment database maintained by ILOSTAT