Reliability of *Engineering News-Record* international construction data

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Abstract

Since the late 1970s, the *Engineering News-Record* (*ENR*) has produced annual lists ranking firms involved in building environment development on the basis of their international revenues. *ENR* lists, such as the Top 225 International Contractors and the Top 200 International Design Firms, have become popular datasets for international construction research. Nonetheless, given that the *ENR* data is self-reported, reviewers for journals and research funding bodies frequently question its reliability. The aim of this research is to ascertain the extent to which the self-report *ENR* data can be considered reliable for international construction research. Inter-data reliability tests conducted to measure the levels of resemblance between the *ENR* data and annual report data of 51 sample companies found that, contrary to the prevalent view that companies reporting to the *ENR* tend to inflate their revenues, there are no systematic errors in the *ENR* data. Although slight discrepancies were found, *ENR* data can be confidently used for international construction research. Journal reviewers and editors should be more open to *ENR* international construction data, rather than taking the default position that the data is inherently and seriously problematic and thus automatically dismissing those studies that use it.

Keywords: International construction, *Engineering News-Record*, international companies, self-report data, data reliability

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Introduction

'International construction' is when a company resident in one country performs work in another country (Ngowi *et al.*, 2005). Globalisation has changed the nature of competition (Hatzichronoglou, 1996); once seen as a local activity, the construction business today is fast becoming an internationally interdependent marketplace (Yang and Lu, 2013). Advanced technology, fast transportation, convenient communication, effective knowledge transfer, integrated markets, and trade liberalisation have all helped construction companies transcend traditional national boundaries and enter the international arena. Against this backdrop, international construction has received significant academic interest over the past few decades.

However, this research suffers from poor quality data. Ruddock (2002) reported that "the fact that data on construction activity are poor and erratic has been acknowledged for a long time: see, e.g. Bon (1990) and Cannon (1994), who consider the usability of existing public and private data and the failure of such data to meet the needs of its users". Meikle and Grilli (1999) and Ruddock (2000), in their studies of the measurement of construction output in European countries, point out that there is no standard international definition for 'construction output' and that the data is not consistent in content. Ofori (2000) proposes a 'central data bank for construction', advocating further the development of regional construction databases for groups of countries. After more than a decade, these ideas are yet to be realised. Ye *et al.* (2009) report that it is quite difficult, if not completely impossible, to collect data for contractors who have international businesses. Data collection in international construction has constantly been hampered by the fact that it involves international transactions, fluctuating exchange rates, diverse accounting procedures, and different statistical standards.

To a certain extent, the situation has been improved since *Engineering News-Record* (*ENR*) began publishing annual lists of the top international firms involved in built environment development in the 1970s. Of particular note is the Top 225 International Contractors (TIC 225) list, which ranks contractors according to general construction contracting export revenue generated from projects

outside each firm's home country (*ENR*, 2012). Companies' detailed revenues in seven regional markets (U.S., Europe, Canada, Latin America, Asia, the Middle East, and Africa) and nine product segments (e.g. General building, Manufacturing, Power, and Water supply) are also reported. Recently, *ENR*'s annual ranking exercises have expanded to include the Top 500 Design Firms, Top 400 Contractors, and Top 200 Environmental Firms lists. These lists, along with the revenue data, have become popular datasets for research on international construction.

At the same time, reviewers for journals and research funding bodies often question the reliability of *ENR* data. The main criticism is that it is self-reported; *ENR* solicits the data from companies and they report the data back on a voluntary basis. It is alleged that these companies tend to inflate their revenues so as to portray themselves in a more positive light, for example, to be a *Fortune 500* company, viewed as a top international contractor, or to outperform competitors. Researchers (e.g. Cook and Campbell, 1979; Garon, 2013) have noted that respondents in general may deliberately misreport data about themselves, to give socially desirable answers or when they realise there is an incentive to do so. This social desirability responding (SDR) is probably the most common methodological criticism of self-report data. Chan (2009) asks "Are self-report data really that bad?", and observes: "Even authors themselves, after being frequently questioned, start to subscribe to the alleged problems, as indicated by the limitations they acknowledged in the Discussion section of their manuscripts". To pose a similar question: Is the self-report *ENR* data really that bad?

The aim of this paper is to ascertain the extent to which *ENR* data can be considered reliable for the purposes of international construction research. In Section 2 a literature review is conducted to summarise: (a) how the data are collected, compiled, and published by the *ENR*, and used by researchers; and (b) criticism and defense of the reliability of self-report data, with a view to informing the research methods adopted in this study. The methods are presented in Section 3, whereby the reliability of *ENR* data was determined by its level of resemblance (*LOR*) to reality; the revenue data revealed by companies in their annual reports is treated as the 'reality'. Subsequently, an 'inter-data reliability' test is conducted to determine the *LOR* of the *ENR* data to

the annual report data. The data analyses are reported in Section 4, and discussion and findings are offered in Section 5. Conclusions are drawn in Section 6 which states, in short, that as no systematic bias (e.g. social desirability responding) is found in the *ENR* data on international construction, and researchers can use it with a high degree of confidence.

ENR data on international construction

Since the 1970s, the *ENR* has performed annual surveys to rank companies engaged in general contracting, specialty contracting, engineering, architecture, planning and studies. Originally, the magazine published two lists: Top 225 International Contractors (TIC 225), and Top 200 International Design Firms (TID 200). The number of lists has expanded in recent years to include: (a) Top 500 Design Firms, (b) Top 400 Contractors, (c) Top 200 Environmental Firms, (d) Top 100 Green Design Firms, (e) Top 150 Global Design Firms, (f) Top 225 Global Contractors, (g) Top 600 Specialty Contractors, (h) Top 100 Design-Build Firms, (i) Top 100 Construction Management-for-Fee Firms, (j) The Top 100 Construction Management-At-Risk Firms, and (k) The Top 50 Program Management-for-Fee Firms.

According to *ENR* (2013), the ranking exercises "attempt to bring structure to an otherwise huge and chaotic industry". The rankings are based on annual revenues at home and abroad, and are further divided into specific market categories. The TIC 225, for example, is published annually in August and ranks the 225 largest world construction contractors, both publicly and privately held, based on general construction contracting export revenue generated from projects outside each firm's home country (*ENR*, 2013). The typical reporting structure includes rankings from past years as well as the present year's ranking, international revenues, total revenues, and new contracts signed. The report also analyses the construction market of each individual firm by examining its regional market and product segments.

The author interviewed an editor of *ENR* at the McGraw-Hill Companies (the magazine's owner) to understand how the data is collected and analysed. According to *ENR*, a survey form, accompanied

by a cover letter and detailed survey guidelines, is sent to construction/design companies three times a year. These firms are solicited to provide the data before a given deadline. That means companies self-report the data on a voluntary basis. The lists compiled from the data are published annually. As a result, they form a series of longitudinal data for research on international construction.

With the purpose of identifying how the *ENR* data is used by researchers, a two-step search was conducted in this study. Firstly, a preliminary computer search using 'ENR' as the keyword was performed in three journals publishing research on this subject: *Construction Management and Economics* (*CME*), *ASCE Journal of Construction Engineering and Management* (*JCEM*), and *ASCE Journal of Management in Engineering.* These journals are chosen in that they not only are highly ranked by construction management (CM) researchers, but also most likely publish papers on international construction. Secondly, a manual screening was conducted to ascertain whether the papers were in fact related to international construction, as the *ENR* also publishes other types of data, i.e., cost indexes. The search led to the identification of a total of 67 papers. A brief summary of the papers is presented in Table 1. Some of the papers identified used the *ENR* data for background information. Others engaged the *ENR* data as the major empirical basis for model formulation or substantiation of their debates. For example, Low and Jiang (2004) used ENR data to compute their OLI+S model (Ownership, Location, Internationalisation, and Specialty model). Ye et al. (2009) used 28 years ENR-based data of the TIC 225 to measure the intensity of competition (IoC) for international construction business. Kim and Reinschmidt (2012) investigated the market structure of the construction industry and the organisational performance of large contractors and design firms using the ENR data that covers the 16 years from 1995–2010. Yang and Lu (2013) applied the ENR data from 2004-2009 to the NW/O-L framework——niche width (NW), niche overlap (NO), and location (L) — to analyse competition and organisational performance in the international construction market. While the usefulness and popularity of ENR data in international construction research can be demonstrated, its reliability is frequently being questioned owing to its self-reported nature. There are opinions that the ENR data should be taken

with a pinch of salt, if it is trustworthy at all.

Table 1 Papers using *ENR* data on international construction

Journal	Total numbers	1980s	1990s	2000s	2010s*
JCEM	29	10	16	24	11
CME	38	1	10	24	3
JME	20	1	7	5	7

* as of December 2013

Criticism and defense of the reliability of self-report data

The term 'self-report data' is often used to refer to "data obtained using questionnaire or surveys containing items that asked respondents to report something about themselves and completed by respondents themselves" (Chan, 2009). Discussion of the reliability of self-report data is certainly not new in construction management (CM) research. Owing to the unique, one-off, and irreversible nature of construction projects, it is difficult or too expensive to put them in a comparative experiment which, e.g. sets up treatment and control groups and derives experimental data. The temporary nature of project teams further complicates data collection in this research domain; important data associated with individual team members often departs with dissolution of the team at project completion. Collection of data through questionnaire surveys and interviews is thus inevitable in CM research; in any case, these data-collection methods are inherently superior when it comes to assessing some personality, attitudinal, and workplace perception constructs such as culture (e.g. Phua and Rowlinson, 2004; Zhang and Liu, 2006), job satisfaction (e.g. Borcherding and Oglesby, 1974), burnout (e.g. Lingard and Francis, 2005), perceived organisational support (Artis, 2007), and fairness perception (Wooten and Cobb, 1999). Nevertheless, the bias against self-report measures has been relentless. This bias is evident in, and reinforced by, Campbell's (1982) remark that "if there is no evident construct validity for the questionnaire measure or no variables that are measured independently of the questionnaire, I am biased against the study and believe that is contributes very little. Many people share this bias". CM researchers who use questionnaire surveys or interviews face the perpetual burden of defending the reliability of their

self-report data.

In the context of international construction as a subset of CM, it is important to distinguish the 'data reliability' under investigation from 'construct validity' and 'instrument reliability'; concerns continually associated with self-report data, particularly in the areas of sociology, psychology, and management science. 'Data reliability' concerns the level of resemblance (*LOR*) of data items to reality (Agmon and Ahituv, 1987) (leaving aside for the time being the questions of how the *LOR* is defined and what 'reality' actually refers to). 'Construct validity' refers to the extent of operationalisation of a construct (e.g. the extent to which an IQ questionnaire actually measures intelligence), while 'instrument reliability' concerns the extent to which an instrument (e.g. an IQ question) yields the same results in measuring a construct on repeated trials. The construct here, in the *ENR* data, is 'revenue'. According to the *Longman Dictionary of Contemporary English*, this is "the money that a business or organisation receives over a period of time, especially from selling goods or services". In comparison to constructs reliant on self-perception such as personality, attitude, and workplace perception, revenue is inherently more measurable.

The relatively clear nature of the construct 'revenue' does not make it automatically immune to measurement errors, particularly when it is self-reported. Normally, two factors underlie the purported unreliability of self-report data: recall bias and deliberate misreporting (Garon, 2013). The human memory is fallible (Schacter, 1999), and one may have difficulty recalling something accurately after a significant amount of time has elapsed (Das *et al.*, 2011; Beegle *et al.*, 2011). With modern accounting systems however, an international construction company will unlikely fail to recall its revenue data. Garon (2013) suggests that even when recall bias is not at play, the reliability of self-reported data may be compromised by respondents' desire to misreport their activities so as to portray their behavior in a more positive light. This is known as social desirability responding (SDR), which can be traced back to Edwards (1957). It is defined by Ganster *et al.* (1983) as the "tendency for an individual to present him or herself, in test-taking situations, in a way that makes the person look positive with regard to culturally derived norms and standards".

Chan (2009) suggests that SDR is "probably the most common methodological criticism against self-report data". Although no source has made a public claim to this effect, international construction companies are commonly alleged to inflate their revenues to portray themselves more positively, for example, to be named a *Fortune 500* company, or to be ranked higher on an *ENR* list. In Chinese state-owned enterprises (SOEs), senior staff members are promoted by the government on the basis of key performance indicators, including the ranking of the SOEs. These SOE staff members, therefore, allegedly have an incentive to inflate their revenues when reporting to the *ENR*.

As previously mentioned, the reliability of *ENR* international construction data can be ascertained by examining data items' *LOR* to reality. Bearing in mind that 'reality' itself is subject to a long history of inconclusive philosophical debate, the revenue data revealed in companies' annual reports is treated as the 'reality'; although this annual report data is also self-reported, by law publicly-listed companies must disclose and maintain the integrity of this data, e.g. through internal and external audits by the financial services authority and professional conduct of chartered accountants. The reliability of *ENR* data can thus be analysed by looking for discrepancies between it and annual report data. This rationale was also adopted by Fredriksson *et al.* (1998) in Sweden to analyse the validity and reliability of self-reported, retrospectively collected data on sick leave related to musculoskeletal diseases. At first glance, this may appear to be a test-retest reliability problem; however, it is not. The instruments used by the *ENR* and annual report producers to collect data are unnecessarily the same. Yu *et al.* (2000) suggest that when the source of error is external to the instrument, such as human error (e.g. deliberate misreporting), inter-rater reliability is more pertinent than test-retest reliability. In this study, the testing of resemblances between *ENR* data and annual report data can be conceptualised as inter-data reliability estimation. Yu *et al.* (2000) suggest that this is similar to inter-rater reliability analysis, and further, that the four ways of estimating inter-rater reliability — Kappa coefficient, Index of Inconsistency (IOI), repeated measures analysis of variance (ANOVA), and correlational and regression analysis — can also be used for inter-data reliability estimation.

Research methods

In this study, the top 225 international contractors (TIC 225) were chosen to represent international construction for four reasons. Firstly, Ye *et al*. (2009) suggest that contractors not ranked in the TIC 225 have negligible market power as their market shares are relatively very small. Secondly, international contracting revenues are the 'root' *ENR* datasets, based on which further analyses (e.g. in the seven regional markets and the nine product segments) are conducted and other top lists (e.g. the Top 100 Design-Build Firms) are produced. Thirdly, being the basic business indicators for any construction company, contracting revenues are likely to be found in annual reports. Lastly, the TIC 225 list has a relatively long history, which means it can provide abundant data samples for examination of data reliability.

The TIC 225 is not a static group, however; some firms drop off the list while others are included consistently. In this study, a sample comprising the top 60 international contractors in the TIC 225 2013 list is used. To examine 60 top international companies' report practice over a time period of eleven years is perceived a robust way to examine their data reliability in general. International revenues of the 60 sampled companies over the past eleven years were derived by browsing *ENR* reports published from 2003 to 2013. It should be noted that the data actually covers revenues from 2002 to 2012, as the *ENR* reports current and preceding year revenues. International contracting revenues for these companies were also collected by examining their annual reports over the same period. This is much more difficult. It is hardly easy to find all 660 (60*11) annual reports even the companies nowadays tend to publish theirs on the Internet. These reports had to be analysed manually to make sure that a data point is actually about construction business from the international market. There are cases that the annual reports released no data on its international business specifically. As a result of this step, a series of pairwise datasets were derived from 51 companies, which provided international revenue data in both ENR and their annual reports. Table 2 shows an excerpt of the datasets.

Table 2 Sample of revenues of top international contracting companies from both *ENR* data and the companies' annual reports

Company name	Revenue	*l*	2002	2003	2004	2005	…	2009	2010	2011	2012
GRUPO ACS, Madrid, Spain	*IR* (m$)	11	1230	1701	2453.5	2486.6	…	5863.5	6562.4	31147.5	42,772.00
	IR' (m€)	11	520	1,197.60	1801.3	2105.5	…	3974.7	4891.8	20649	32,421
HOCHTIEF AG, Essen, Germany	*IR* (m$)	11	10010	10252.3	12632	14733.3		23769.5	27424.7	31870.7	34,563.30
	IR' (m€)	11	9991.3	8621.5	9721.4	11383		16024	18517.6	21227	23,670.40
BECHTEL, San Francisco, Calif., U.S.A.	*IR*(m$)	11	2920	6637	8105	7662	…	14849	12500	16700	23,255.00
	IR'(b$)	2	2.6	6.6	-	-	…	-	-	-	-
SAIPEM, San Donato Milanese, Italy	*IR* (m$)	6	-	-	-	-	…	10884.7	11604.9	14110.1	13,770.70
	IR'(m€)	11	3101	4025	4100	4330	…	9153	10368	12050	12,789.00
SKANSKA AB, Solna, Sweden†	*IR* (m$)	11	11520	11504	11436.3	11904.3	…	12880	11632.3	12339.4	13,291.60
	IR'(m€)	11	13951	14056	14138.3	14983.9	…	16,322.00	14,635.50	16,232.60	17,217.00
China CCCC Group Ltd. Beijing, China†	*IR* (m$)	8	-	-	-	839.8	…	7477.8	7134.2	9546.9	11,187.20
	IR'(m*CNY*)	8	-	-	-	12693	…	21958	27151	32151	38,950.00
SAMSUNG Co. LTD., S. Korea	*IR* (m$)	9	-	401	603	-	…	2618.3	3070	5907.3	8,651.90
	IR'*(bKRW)*	7	352.736	472.0786	608	317.231	…	-	-	-	-

l is the number of the available data in the dataset, *IR*=*ENR* international revenues, *IR'*=Annual report international revenues - =Not Available, m$=million US dollars, m€=million Euros, b$=billion US dollars, mCNY = million Chinese Yuan, and bKRW=billion Korean won.

Amongst the 51 sampled companies, 24 were from Europe, 7 from the US, 7 from South Korea, 5 from China, 4 from Japan, 2 from Australia, 1 from India, and 1 from Brazil. With mergers and acquisitions (M&As) frequently taking place across national borders, it is not as easy as it used to be to determine a construction company's 'nationality'. For example, the highest-ranked company in the 2013 TIC 225, Grupo ACS from Spain, holds the second highest, Hochtief from Germany; at the same time, Leighton, an Australian construction company that is often ranked in the TIC 225 list, is a subsidiary of Hochtief. It is thus no longer completely valid to state that Leighton is an Australian company, or that Hochtief is a German company. 'Nationalities' can therefore only be treated as the 'national origins' of a company. In addition, although the sampled companies were ranked in the top 60 in 2013, they may have occupied other positions in the list over the years, or not have been ranked at all. For example, the South Korean construction giant Samsung Engineering Co Ltd. lost its TIC 225 list position in 2002 and 2005; therefore, Table 2 shows no data for these years. While most companies have *ENR* data across the full 11-year period, others have data for a time period ranging from 3 to 10 years. European companies, in their annual reports, tend to release their financial data in accordance with the International Financial Reporting Standards (IFRS); US companies normally do so in the Form 10-K as required by the US Securities

and Exchange Commission (SEC). For easier verification, the units of revenues accord with their data sources and are not at this stage normalised to USD.

Amongst the abovementioned four ways to estimate inter-rater/inter-data reliability, only ANOVA was found to be applicable in this study. Kappa coefficient and IOI are suitable when the reported items are discrete and categorical (i.e., binary 'yes' or 'no', or the Likert Scale, say, ranging from 1 to 5), wherein the probabilities of an observer's rating on individual categorical options can be estimated. In this study, the revenues of the companies are continuous and cardinal data ranging from a few hundred to thousands of millions in monetary terms. It would be extremely cumbersome to normalise the revenue data to categorical options. Correlational and regression analysis is an approach whereby one set of scores (e.g. annual report data) is treated as the predictor while another set of scores (e.g. *ENR* data) is considered the dependent variable to examine their correlations. However, this analysis cannot reveal the *LOR*. For example, the correlation Pearson's *r* between Dataset 1:(1,2,3,4) and Dataset 2:(6,7,8,9) is 1, indicating a perfect positive relationship between the two datasets. But it cannot be claimed that Dataset 1, herein assuming it is the *ENR* data, fully resembles Dataset 2, assuming it is the annual report data. Both ANOVA and *t*-test provide a statistical test to ascertain whether or not the means of groups are statistically equal. The major difference lies in that *t*-test is suitable for two groups while ANOVA is for several groups. Therefore, a two-sample *t*-test meets the requirements for inter-data reliability testing in this study.

A simple instrument as shown in Equation (1) was designed to indicate the pairwise inter-data *LOR*:

$$LOR_{ij}=x_{ij}/y_{ij} \qquad (1)$$

Where x_{ij} is data in the groups to be examined, say, the *ENR* international revenue of company *i* in year *j*; y_{ij} is data in the groups using as a criterion, say, the annual report international revenue of company *i* in year *j*; and *LOR* is the level of resemblance between the data in the examined group and its counterpart in the criterion group. The mean *LOR* can be calculated using Equation (2):

$$\overline{\boldsymbol{LOR}_{\boldsymbol{i}}} = \frac{\mathbf{1}}{\boldsymbol{l}}\sum \boldsymbol{LOR}_{\boldsymbol{ij}} \qquad (2)$$

where LOR_{ij} is defined in Equation (1); $\overline{\boldsymbol{LOR_i}}$ is the mean *LOR* of company *i* or for all companies; and *l* is the length of the dataset of company *i* or for all companies. When $\overline{\boldsymbol{LOR}}$ is larger than 1, the mean of the *ENR* revenues is larger than that of the annual report revenues. Likewise, When $\overline{\boldsymbol{LOR}}$ is smaller than 1, the mean of the *ENR* international revenues is smaller than the mean of the annual report international revenues. The closer the $\overline{\boldsymbol{LOR}}$ approaches 1 and the smaller the standard deviation (SD), the greater the resemblance between the pairwise datasets. The SD shows how scattered the examined group is in deviating from the criterion group. Raw data from either the *ENR* or annual reports varies significantly from one company to another. By using this instrument, the raw data is normalised to a series of *LOR*s close to the criterion point of 1, which are amenable to further statistical analyses such as two-tail *t*-tests and cluster analyses. Detailed data analyses will be elaborated later.

To deepen understanding of the analytic results, an interview was conducted in September 2013 and another in November 2013. The two semi-structured interviews involved a series of email communications surrounding the open-ended questions initiated by the author. The questions include, for example, Where can I have a copy of the data collection forms? Is there any verification process after you receive the data? Are there any "problems" encountered when the surveyed contractors or designers respond to your survey? The first interviewee (hereafter Interviewee A), as mentioned previously, is a Senior Editor of *ENR* who has been responsible for *ENR* data for more than 10 years. Interviewee A provided some factual background on *ENR* data collection, compilation, and publication. Some measures to ensure the data accuracy and reliability were explained and potential problems in the *ENR* data were also discussed. No strong preference regarding data reliability was detected in this interview. The second interviewee (hereafter Interviewee B) is a senior figure in international construction research with extensive contacts amongst the top international contractors/designers. Interviewee B offered some unpublished stories on *ENR* data from both *ENR* and international contractors' perspectives. The qualitative interview

data obtained was largely used as background information to supplement the statistical analyses to help understand *ENR* data reliability.

Data analyses and results

Preliminary data processing

Firstly, all the revenues were normalised to USD by retrieving the annual average exchange rates (e.g. from EUR, GBP, CNY to USD) in each respective year from OANDA, a website providing historical exchange rates. Secondly, rather than trying to deal with missing data using mathematical methods such as imputation, company data in a specific year was kept only when both *ENR* data and annual report data could be found. This left 51 companies with 377 pairs of revenues (See Table 1). Thirdly, the revenues were plotted in the two-dimensional coordinate system so that their resemblance could be perceived graphically. To provide a clear view, only three firms were randomly selected and their international revenues plotted in Figure 1. It can be seen from Figure 1 that the pairs of datasets, *ENR* international revenues versus annual report international revenues, closely resemble each other. In particular, the curves for the selected company ROYALBAM overlap almost perfectly, indicating a high level of resemblance between the datasets. However, more robust statistical analyses were desired to ascertain the extent to which the *ENR* data resembles the annual report data.

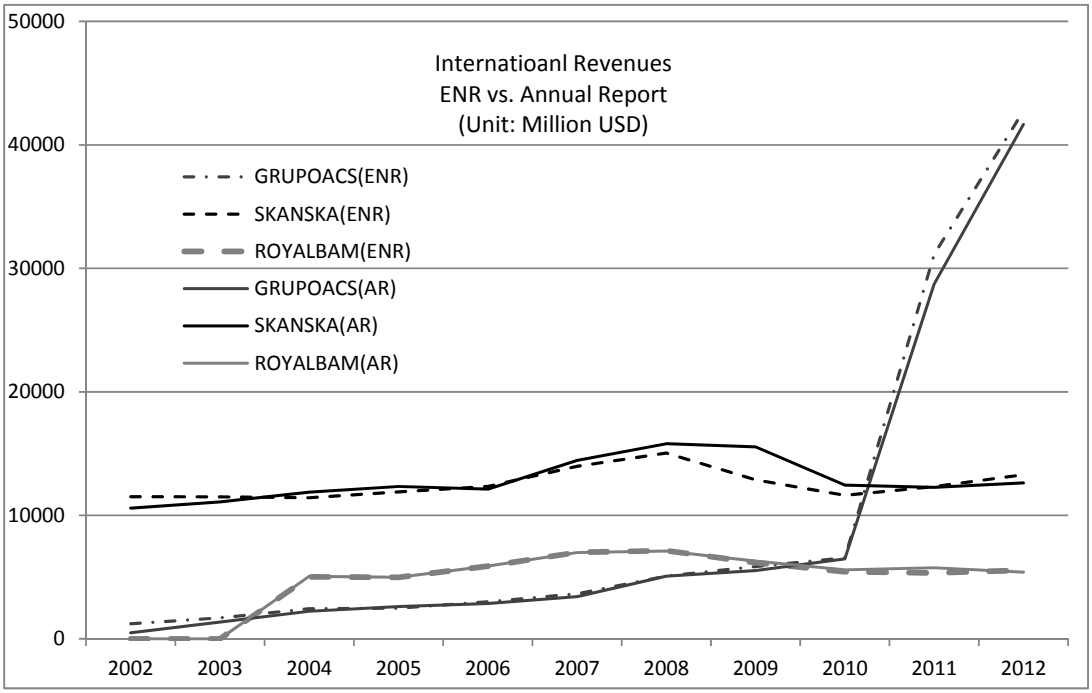

Figure 1 ENR international revenues and annual report international revenues of three top companies

Two-sample t-tests

By applying Equations (1) and (2) to all companies, the mean *LOR* and SD of all companies' international revenue data could be calculated. This involved treating all the companies as a homogeneous group (N=377), regardless of their company profiles or reporting years. As shown in Table 3, the result of a two-sample *t*-test shows no significant difference between the *ENR* data and the annual report data. The mean *LOR* 0.984 and the relatively low SD 0.344 together indicate a high level of resemblance between the two datasets. Overall, *ENR* revenues are smaller than their counterparts in the annual reports, which can be perceived as slightly under-reported to *ENR* by the sample companies. However, in statistical sense, there is no significant discrepancy between the two international revenue datasets.

Table 3 *t*-test of the level of resemblance between the international revenues of all companies

Firms	*l* (N)	$\overline{LOR}$	Standard Dev.	t-Statistic	$t_{0.05}$ (Two tails)	Significant difference between *ENR* and annual report data? (Y/N)
ALL	377	0.984	0.344	-0.887	1.96	N

l is the number of the available data in the dataset, also used as the sample size *N* in the *t*-test.

Further analyses were conducted to ascertain the *LOR* of the two datasets at company level. By applying Equations (1) and (2) to all individual companies, the mean *LORs* and SDs of all the companies' international revenue data was calculated, as shown in Table 4. To save space, only an excerpt of the statistical analytic results was listed. It can be seen from Table 4 that companies show different *LORs* between *ENR* and annual report data. Factors such as fluctuating exchange rates, diverse accounting procedures, and different statistical standards may account for these different *LORs*. In the next step, cluster analysis was conducted to help group the firms based on their mean *LORs*. It was hoped that this analysis would discover important information, e.g. whether or not a certain group is apt to inflate or under-report their revenues to the *ENR*.

Table 4 *t*-test of the level of resemblance between the international revenues of individual companies

Firm	*l* (N)	$\overline{LOR}$	Standard Dev	t-Statistic	$t_{0.05}$ (Two tails)	Significant difference between *ENR* and annual report data? (Y/N)
GRUPOACS	11	1.193	0.443	1.377	2.228	N
HOCHTIEF	11	1.075	0.031	7.757	2.228	Y
BECHTEL	2	1.064	0.083	0.775	12.7	N
VINCI	11	0.996	0.015	-0.760	2.228	N
FLUOR	11	0.857	0.045	-9.985	2.228	Y
STRABAG	8	1.152	0.185	2.178	2.365	N
BOUYGUES	11	0.957	0.044	-3.074	2.228	Y
SAIPEM	6	0.874	0.054	-5.244	2.57	Y
SKANSKA	11	0.983	0.070	-0.761	2.228	N
CHINA CCCC	8	1.654	0.708	2.445	2.365	Y
CONSTRUTORA	11	0.582	0.066	-19.934	2.228	Y
SAMSUNG	5	1.091	0.238	0.762	2.776	N
FCC	11	1.009	0.019	1.491	2.228	N
HYUNDAI	11	0.782	0.209	-3.291	2.228	Y
BILFINGER	11	1.039	0.051	2.420	2.228	Y
BALFOUR	11	0.919	0.207	-1.238	2.228	N
PETROFAC	5	1.187	0.098	3.826	2.776	Y
ROYALBAM	9	0.990	0.028	-0.978	2.306	N
SINOHYDRO	2	0.963	0.002	-20.442	12.7	Y
OHL	6	1.091	0.195	1.040	2.571	N
DAELIM	3	1.452	0.136	4.680	4.303	Y
SALINI	4	0.909	0.709	-0.223	4.541	N
GS	8	1.118	0.190	1.646	2.365	N
KBR	8	0.828	0.100	-4.538	2.365	Y
ABEINSA	8	1.006	0.026	0.603	2.365	N
LEIGHTON	11	0.9037606	0.1837883	-1.655904	2.228	N

JGC	11	0.9078811	0.1807884	-1.6113072	2.228	N
LEND LEASE	3	0.8369429	0.1018495	-3.3209811	4.303	N
CHINA RAILWAY	7	1.4745729	0.5801838	1.2795413	2.447	N
SK E&C	7	1.0039155	0.0523894	0.1169133	2.447	N
SAMSUNG C&T	6	1.0991015	0.0862759	2.5684777	2.571	N
CB&I	9	0.912737	0.125769	-1.9624635	2.2306	N
TECNICAS REUNIDAS	10	1.2876203	0.6197522	1.3922679	2.262	N
DAEWOO E&C	7	0.2658949	0.0966449	-18.606089	2.447	Y
DANIELI & C	5	0.7304162	0.1573821	-3.4258503	2.776	Y
MCDERMOTT	7	0.6785373	0.2562966	-1.9620256	2.447	N
…	…	…	…	…	…	…

l is the number of the available data in the dataset, also used as the sample size *N* in the *t*-test.

Cluster analyses

Cluster analysis is the task of grouping a set of objects in such a way that objects in the same group are more similar to each other than to those in other groups. Cluster analysis is a technique proven to be effective in identifying and grouping similarities among individuals (Shen *et al.*, 2006). Amongst the many cluster analysis algorithms, *k*-means clustering aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. Given its suitability, *k*-means clustering was conducted using R, which is an open source statistical analytical software program, on all the firms based on their mean *LOR*s. Results are shown in Table 5 and Figure 2. Four clusters were derived based on the biggest change of Euclidean distance.

Table 5 Cluster analysis of companies in reporting their international revenues

Firm	$\overline{LOR}$	Clusters (K=1, 2, 3, 4)	Firm	$\overline{LOR}$	Clusters (K=1, 2, 3, 4)
CONSTRUTORA	0.582	4	VINCI	0.996	1
DAEWOO E&C	0.246	4	FLUOR	0.857	1
DANIELI & C	0.730	4	BOUYGUES	0.957	1
MCDERMOTT	0.678	4	SAIPEM	0.874	1
FOSTER W.	0.699	4	SKANSKA	0.983	1
GRUPO C.I.	0.504	4	FCC	1.009	1
JACOBS	0.479	4	HYUNDAI	0.782	1
GRUPOACS	1.193	2	BALFOUR	0.919	1
HOCHTIEF	1.075	2	ROYALBAM	0.990	1

BECHTEL	1.064	2	SINOHYDRO	0.963	1
STRABAG	1.152	2	SALINI	0.909	1
SAMSUNG	1.091	2	KBR	0.828	1
BILFINGER	1.039	2	ABEINSA	1.006	1
PETROFAC	1.187	2	LEIGHTON	0.904	1
OHL	1.091	2	JGC	0.908	1
GS	1.118	2	LEND LEASE	0.837	1
SAMSUNG C&T	1.099	2	SK E&C	1.004	1
TECNICAS REUNIDAS	1.288	2	CB&I	0.913	1
OBAYASH	1.069	2	KAJIMA	0.905	1
LARSEN & TOUBRO	1.198	2	MAIRE TECNIMONT	0.925	1
ACCIONA	1.159	2	CHINA RAILWAY	1.021	1
TOYO ENGINEERING	1.237	2	SACYR VALLEHERMOS	1.018	1
MOTA-ENGIL	1.053	2	VAN OORD	0.996	1
CHINA CCCC	1.654	3	ASTALDI SPA	1.002	1
DAELIM	1.452	3			
CHINA RAILWAY	1.475	3			
CHINA GEZHOUBA	1.585	3			

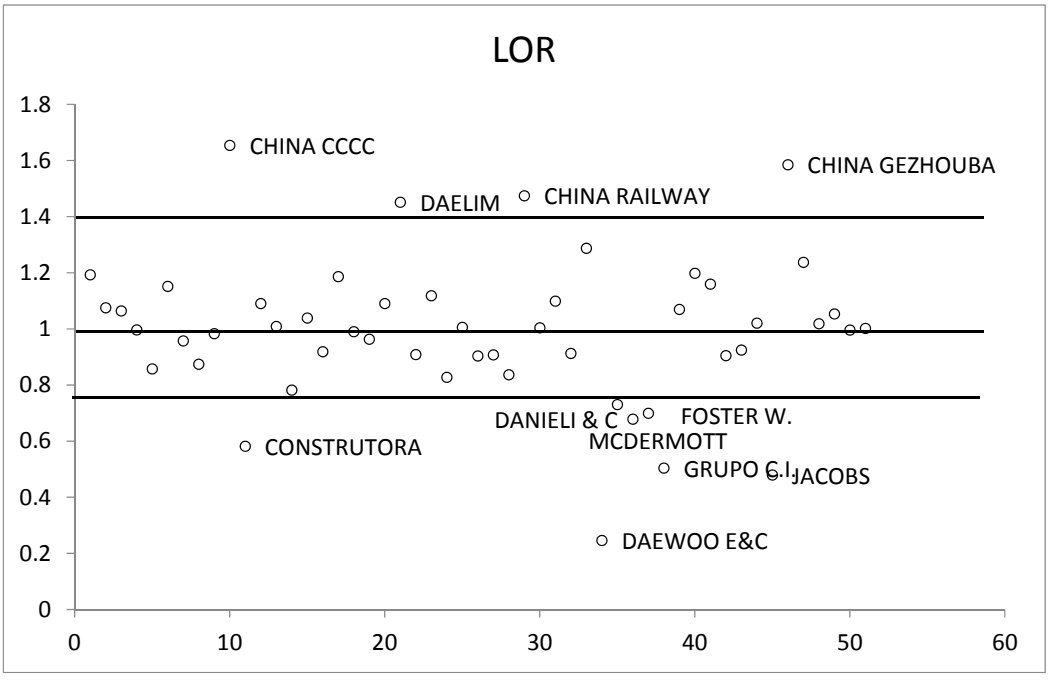

Figure 2 Groupings of companies based on mean *LORs* using cluster analysis method

It can be seen from Figure 2 that, the *LOR*s of most of the companies fall within the range of [0.75, 1.4], showing a relatively high level of resemblance between the *ENR* data and the annual report data. This resonates with the analytical results in Figure 1 and the *t*-tests – *ENR* data on international construction is reliable (Table 3). Figure 2 shows that the companies randomly dispersed on the two sides of the criterion line; some companies' international revenues reported to the *ENR* are slightly larger than those announced in the annual report, while other companies' are not. No systematic misreporting was found in the *ENR* data.

Two-sample t-tests by clustering companies in nationalities

Regarding the allegation that companies from a particular background may have idiosyncrasies in reporting their revenue data to the *ENR*, two-sample *t*-tests were performed within the groups clustered by national origins. Companies from the same country/region were treated as a homogeneous group and *t*-tests conducted to determine whether there is a significant difference between the *ENR* and annual report international revenues data. As can be seen from Table 6, except for the 15 companies from Australian, Brazilian, Chinese, and US groups, national origin groups of firms show no significant difference between *ENR* and annual report data in the rest 36 companies.

Table 6 Two-sample *t*-tests by clustering companies in nationalities

National origins	Firm numbers	Firms	*l* (N)	$\overline{LOR}$	Standard Dev.	t-Statistic	t0.05 (Two tails)	Significantly different? (Yes/No)
Australia	2	LEIGHTON, LEND LEASE	14	0.889	0.168	-2.366	2.16	Y
Brazil	1	CONSTRUTORA	11	0.582	0.066	-19.934	2.228	Y
China	5	CHINA CCCC, SINOHYDRO, CHINA RAILWAY, CHINA RAILWAY CONSTRUCTION, CHINA GEZHOUBA	27	1.426	0.558	3.057	2.056	Y
Europe	24	GRUPOACS, HOCHTIEF, VINCI, STRABAG, BOUYGUES, SAIPEM, SKANSKA, FCC, BILFINGER, BALFOUR, PETROFAC, ROYALBAM,	184	1.021	0.275	1.051	1.96	N

		OHL, SALINI, ABEINSA, TECNICAS REUNIDAS, DANIELI & C. OM SPA, GRUPO ISOLUX CORSAN SA, ACCIONA, MAIRE TECNIMONT, SACYR VALLEHERMOSO, MOTA-ENGIL, VAN OORD, ASTALDI SPA						
India	1	LARSEN & TOUBRO	9	1.198	0.534	1.051	2.2306	N
Japan	4	JGC, OBAYASHI, KAJIMA, TOYO ENGINEERING	32	0.973	0.235	-0.639	2.043	N
S. Korea	7	SAMSUNG, HYUNDAI, DAELIM, GS, SK E&C, SAMSUNG C&T, DAEWOO E&C	47	0.911	0.356	-1.688	2.01	N
U.S.	7	BECHTEL, FLUOR, KBR, CB&I, MCDERMOTT, FOSTER WHEELER AG, JACOBS	53	0.774	0.189	-8.636	2	Y

l is the number of the available data in the dataset, also used as the sample size *N* in the *t*-test.

These results should be treated with caution. As shown in Table 7, the *ENR* data for CONSTRUTORA is significantly different from its annual report data, judging by the low $\overline{LOR}$ and the relatively small SD. The author double-checked the revenues data in both the *ENR* and annual reports, confirming both positively. The company has unambiguously reported its international revenues to *ENR* and in annual reports over the past eleven years, but there is no explanation for this discrepancy. Regarding the five Chinese companies, there is a significant difference between their *ENR* data and annual report data. Companies like SINOHYDRO reported in a consistent way both to ENR and in their annual reports, while there is a considerable discrepancy between ENR revenues and annual report revenues reported by CCCC and GEZHOUBA. The temptation is to say there is deliberate misreporting or inflating but amongst the 27 instances of reporting by these companies over the years, they under-reported or reasonably reported their international revenues to the *ENR* fifteen times. It is better to understand that the Chinese companies are probably struggling to deal with changing accounting standards in the transition to international practice. The two Australian companies, LEIGHTON and LEND LEASE

have shown discrepancy between ENR and annual report revenues, but in recent years, the mean *LORs* are converging to 1. As for the seven US companies, strangely, there is a statistically significant difference between the *ENR* and annual report data reported, the mean *LOR* of 0.774 and the relatively small *SD* of 0.189 imply that the companies were consistent in under-reporting their international revenues to the ENR (See Table 6). One may notice that those companies growing from engineering consultancy such as MCDERMOTT, FOSTER WHEELER, and JACOBS significantly under-reported their construction revenues, evident by the low *LORs* in Table 7. It may be attributed to the difficulty to appropriation the construction business in Design & Building or engineering procurement and construction (EPC) contracts, as suggested by Interviewee B later in this paper. The data reported by the rest of the examined companies, e.g. the 15 European, 7 South Korean, 4 Japanese, and 1 Indian company, 'stabilized' the sample.

Discussions

The results of this study indicate that by examining all the sampled companies holistically, *ENR* data contains no systematic bias. Nevertheless, the data at company level should be trusted with different degrees of confidence. The interviews will help understand how the data is collected, and the ways to improve the reliability from both ENR and individual companies' perspectives.

The *ENR* has adopted a series of verification processes to ensure the reliability of its international data. According to Interviewee A,

> *"We ask that all survey data be accompanied by the signature of a senior officer of the company responding to the survey, verifying that the data is accurate. We also review revenue data against previous submissions looking for anomalies or odd spikes or drops in the revenue data or in the market sectors companies work in. I also check other ranking lists around the world to see if we have data that is out of line with their results. For Chinese contractors, we have the China International Contractors Association in Beijing collect and review the revenue data for accuracy".*

He further emphasized that:

"When we encounter a problem with a survey response, we contact the company and ask them to explain the anomaly or risk being excluded from the ranking. This generally results in a quick explanation and, in many cases, an adjustment of their figures. We also have excluded companies from ranking that fail to answer our concerns".

Yet, there are still some discrepancies between the *ENR* and the annual report data that should not be overlooked. These may be attributable to differing accounting timelines; some companies count a calendar year while others use a fiscal year. As mentioned above, firms are increasingly converging to the IFRS, which are designed on a calendar year basis. According to Interviewee A,

"We ask that firms report their revenue for the previous calendar year. In some cases, they cannot make the breakdown, so we do accept fiscal year data. About 10% of the surveys come in based on a fiscal year, rather than a calendar year basis".

Exchange rate is another factor contributing to discrepancies. Interviewee A stressed the impact of this factor, reflecting that:

"We ask companies to adjust their local currencies to the interbank exchange rate in effect on 31st December of the reporting year to make sure sudden currency fluctuations do not skew the results".

Annual reports normally release revenues in local currencies, e.g. British companies release revenues in pounds sterling, and European companies in euros. Revenue data released in annual reports may, however, have been distorted to unknown extent due to companies exchanging their international revenues from foreign currencies to their local currency. The data could have been further slightly distorted in this study due to the adoption of annual average exchange rates, rather than the exchange rates on the 31st December of each reporting year.

The ambiguity of revenue itself also accounts for some discrepancies. In Section 2, it was argued that 'revenue' is a less ambiguous construct than self-perception-related constructs and is therefore

more measurable. However, the concept of "revenue" is marked by ambiguity in international construction business. Interviewee B reflected that:

> *"Stock Exchange rules around the world have different reporting requirements. For example, in some countries if you are the construction manager, you can only account for your fee income and direct expenditure as revenue, whereas in others the project value is accounted as revenue. This has a huge influence by distorting the real size of the business. Japan is a case in point where their accounting rules for construction businesses make it difficult to compare EBIT (Earnings before interest and taxes)".*

Interviewee B further pointed out that:

> *"Turning to the Chinese reported figures, these have distorted the ENR list because companies like China Railways are reporting group revenue, rather than construction revenue. They also include the design bureau's revenue in gross revenue".*

Interviewee B seemingly has pointed out the reason accounting for the large discrepancies existing in Chinese companies as shown in Tables 6 and 7. Nowadays, international construction companies are increasingly involved in business other than contracting through different procurement models such as Build-Operate-Transfer (BOT), Public-Private Partnership (PPP), and Engineering Procurement and Construction (EPC) (Lu *et al.*, 2013). Disentangling contracting revenues is more difficult than ever. This was echoed by Interviewee B:

> *"…with BOT/PPP projects, there are issues about whether it is purely construction revenue, or whether the project revenue is recorded. Another issue is when EPC figures are being reported, this means that Bechtel's figures are over inflated as the E and P part is subsumed into the revenue".*

The difficulty has further been well reflected in the reporting practice by the US companies with an engineering consultancy root; with matured market operations and accounting systems, these companies would not have reported so inconsistently if contracting revenues are easy to be disentangled.

What is seen as the biggest problem by the *ENR* itself is double-counting of international revenues.

With the increase in M&As across national borders, it is not uncommon for one company to own a share of another reporting contractor. According to Interviewee A:

> *"We do not exclude a company simply because another company owns shares in that company, even if the company in effect owns a controlling interest in the company. This can result in double counting of revenue, which we have sought to avoid".*

An example given by the interviewee and also, unintentionally, investigated above is that of ACS, Hochtief, and Leighton. Interviewee A reported that:

> *"We have situations like Hochtief, which owns about 54% of Leighton Holdings' shares. We allow both to be listed, even at the risk that some of Leighton's revenue is being double counted through Hochtief. The same happened when ACS acquired a controlling share of Hochtief. In that case, there is significant double counting".*

This is why, in Figure 1, there is a spike in ACS' international revenues reported in both the *ENR* and its annual reports. To avoid double counting, Interviewee A said that:

> *"We do not allow a wholly owned subsidiary to participate in the survey if the parent company already participates and already includes the subsidiary's revenue in the parent's reporting".*

He further reported some unusual cases:

> *"ENR is not interested in contractors engaged in single-family homebuilders. We do not ask contractors specifically to exclude revenue from building single family housing, but do not pursue pure homebuilders, like Japan's Daiwa House".*
>
> *"Many large construction firms simply do not respond. For example, many large construction firms in the U.K., like Carillion and Laing O'Rourke, do not respond".*

This double-counting or miss-counting may cause problems when the *ENR* data is supposed to help draw a full picture of, say, overall international construction business volume. However, the data is reliable in terms of what it is intended to measure, such as the revenues of a company in a specific business segment in a specific year.

Neither interviewee referred to the potential for socially desirable answers in reporting to the *ENR*,

but did, as can been seen above, enumerate the factors that could distort the revenue data. The statistical analyses described above indicate a high level of resemblance between *ENR* data and the corresponding annual report data by the sample companies. A mean *LOR* of 0.984 and a small SD of 0.344 over a sample of 377 pairs of data points are certainly not a result of luck; rather, they imply that the *ENR* data should be accepted as reliable with a high level of confidence. Compared to annual report data, *ENR* data is more systematic and informative, allowing researchers to examine international construction in a specific sub-sector (e.g. a region or a product segment) or across sub-sectors. The *ENR*'s ranking exercises over the years have created sets of panel data, on the basis of which researchers can examine international construction longitudinally. Based on the above analyses, this paper calls for a moratorium on the bias against *ENR* international construction data and suggests that researchers should use this data confidently. Another implication of the arguments in this paper is that reviewers and editors should be more open to *ENR* international construction data, rather than automatically dismissing those studies that use it.

Yet, it is not the intention of this paper to suggest that *ENR* has done perfectly and the *ENR* data on international construction should be accepted without allowing any room for doubt. The analytic results show that many companies did report international revenue data inconsistently to ENR and in their annual reports. The reasons leading to the discrepancies have been explored in this paper. Interviewee B suggested the way forward:

> *"The ENR collection system needs an update and ENR is aware of that. …What is needed in a digital world is a way to sort the data in a more meaningful way, by slicing and grouping".*

Specifically, for example, *ENR* needs to tighten the quality control over data collection surveys via its agent the China International Contractors Association rather than relying on the latter solely. *ENR* should also provide more specific survey guidelines for those companies with multiple business lines to disentangle and report their international construction revenues.

Conclusions

This research examines the reliability of self-report *ENR* international construction data, which has received its fair share of criticism owing to its self-reported nature. By investigating fifty-one top international construction companies' reporting data over the past eleven years, this research found no systematic errors in the data caused by alleged deliberate misreporting, although there are some discrepancies between the *ENR* and the annual report data that should not be overlooked. The discrepancies can be attributable to factors such as different accounting timelines, exchange rates, and the ambiguity of international construction revenue itself, which is particularly difficult to be disentangled if a company is involved in multiple business lines or integrated procurement models, i.e. BOT, PPP, and EPC. One of the practical implications is that, in order to increase the reliability of its international construction data, *ENR* should continue to improve its data collection strategies, e.g. by providing more specific survey guidelines for those companies to disentangle and report their international construction revenues.

Through a holistic examination of all sampled companies, it does find that the overall quality of the *ENR* data is reliable. Another practical implication is that researchers can use this data with a high level of confidence. As a result of its persisting reporting exercise, *ENR* provides a data hub that focuses on international construction, perhaps unintentionally though. *ENR* has also formed a series of longitudinal data, including construction companies' revenues in specific regional markets (e.g. U.S., Europe, and Asia), and their revenues in a specific product segment (e.g. building, and oil&gas). These detailed datasets are very useful for international construction research, for example, to analyse construction companies' internationalisation strategies, market penetration, diversification, merger & acquisition, and so on. Based on the analyses, a call for a moratorium on the bias against *ENR* international construction data is made in this paper; journal reviewers and editors should no longer take the default position that self-report *ENR* data is inherently and seriously problematic and thus automatically leads to fallacious inferences.

Unavoidably, there are limitations in this paper. Firstly, the *ENR*'s full list of international construction companies has not been examined. The sample size may be too small to yield further

robust statistical results, particularly when examining the data at a company or regional level. Secondly, the data analysis methods applied could be improved upon. For example, at some point in the future (when the datasets are good enough), unbalanced panel analyses could be conducted with the aim of yielding more robust analytical results.

Acknowledgements

The work is supported by the Hong Kong Research Grants Council (RGC) General Research Fund (GRF) (Project No.: HKU 749312B). Dr. Yi PENG, Mr. Kevin WONG, Mr. Leo CHEN, and Mr. Cong LIANG provided great help in collecting the data. Special thanks to the two interviewees and the four reviewers who provided invaluable insights into this research topic.

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