Measuring the Construction Industry's Productivity Performance: Critique of International Productivity Comparisons at Industry Level

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Abstract: The authors review work on international comparisons of construction productivity performance by providing an in-depth critique of the existing literature and highlighting the existing methodological challenges. Using studies and data on the United Kingdom's relative construction productivity performance as an exemplar, it is suggested that any investigation of international productivity differences in construction at the industry level is highly problematic because these productivity estimates do not compare like for like. Data definitions and coverage differ substantially across countries. In addition, deflators and exchange rates used to convert output into a common currency are unreliable. While the new standard industrial classifications 2007 could provide a better basis of cross-country productivity comparisons and further research on deflators, conversion rates, labor inputs, and capital stock estimates could improve the robustness of international comparisons, there are conceptual limitations to an industry-level approach. This paper's contribution is to discuss these methodological challenges in detail and propose a research agenda for enhancing cross-country productivity comparisons for informing government policy intervention on productivity improvement. The authors argue that cross-country productivity at the project level can enable a more detailed analysis of the tangible and intangible inputs to the construction process while accounting for the heterogeneous nature of the industry. However, the existing project-based productivity measures fall short of providing a common framework for systematically gathering comparable cross-country productivity data that could enable robust benchmarking. The authors conclude by calling for the need of facilitating the collection and analysis of robust project-level productivity data, e.g., through an international benchmarking club, in order to support effective policy intervention for enhancing construction productivity performance. **DOI:** 10.1061/(ASCE)CO.1943-7862.0000944.

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Introduction

Productivity is a key driver for economic growth and prosperity in any country. Higher productivity translates into higher wages, profits, and tax revenue, cheaper and often better products, and services for customers, and thus benefits the society as a whole.

An economy's productivity performance can only be as good as the performance of its constituent parts. The construction industry is a significant contributor to the economy in most countries. According to Arditi and Mochtar (2000), the construction industry accounts for 6–8% of an economy's gross domestic product (GDP). An improvement in construction productivity performance would not only raise profits and earnings in the sector, but could provide substantial cost savings. For example, an increase of 10% in the U.K. construction labor productivity is equivalent to a saving of £1.5 billion to the industry's clients; sufficient to procure perhaps an additional 30 hospitals or 30,000 houses per year (Horner and Duff 2001). Furthermore, the built environment is the nation's largest asset. Built assets account for approximately 66–90% of all manufactured wealth, and are thus an important input to the production processes of other sectors (Pearce 2003).

Improving the productivity of the construction industry has therefore been at the heart of government's and industry's agenda leading to various policy initiatives. An example can be found in Sir John Egan's Construction Task Force, which delivered a report, *Rethinking Construction*, on the scope for improving the quality and efficiency of U.K. construction [Department of the Environment Transport and Regions (DETR) 1998]. Crucially, any such policies should be driven by an analysis of the available evidence on the industry's performance. This evidence in turn should address questions like the following: How does the productivity performance of the sector compare internationally or to other sectors in an economy? If there are productivity gaps, what explains them? Has productivity improved over time? What are the key industry-specific drivers of productivity on which policy initiatives should focus? Have industry-specific policies been successful in enhancing productivity?

The initial report of Sir John Egan's Construction Task Force acknowledged that solid data on performance in terms of efficiency and quality are hard to come by and that the construction industry must also put in place a means of measuring progress towards its objectives and targets.

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"The industry starts with a clean sheet in this respect. It has a great opportunity to create an industry-wide performance measurement system" (DETR 1998, p. 18). While there have been substantial efforts on developing industrywide performance measures, they still provide poor policy and industry guidance. Recently, the Scottish Construction Industry Strategy (2013) has acknowledged that "Robust baseline data from which we can monitor and track the performance of the Scottish Construction Industry is often unavailable." Furthermore, it is argued that research and development, benchmarking, and learning from other regions and countries will be central to both the understanding and application of productivity improvements in the industry. Industrywide databases, such as the European Union (EU) KLEMS, provides overall trends of cross-country productivity performance (Abdel-Wahab and Vogl 2011), but they are plagued with methodological challenges. The authors argue that the existing body of knowledge is deficient because it inhibits the development of robust construction productivity policy interventions.

Therefore, the aim of this paper is to conduct an in-depth review on cross-country productivity comparisons and highlight such methodological problems that inhibit policy development. There is a paucity of papers that attempt to synthesize the existing literature in productivity research. An example of such attempts is the recent work of Yi and Chan (2014), which identified the common themes in construction labor productivity (CLP) research, such as modeling and evaluation of CLP and trends and comparisons of CLP. Similarly, Dolage and Chan (2014) found that construction productivity research predominately focused on the "measurement of productivity" and "examining the casual relationships with productivity." A similar approach is also adopted by Panas and Pantouvakis (2011), but taking one step further by attempting to classify existing construction productivity research themes by the research method used, namely, qualitative, quantitative, and mixed method.

Overall, the few attempts of reviewing construction productivity research focuses on producing a broad thematic overview and it falls short of providing an in-depth critique of the methodological challenges associated with the research under each theme.

This paper therefore addresses this research gap by providing a critique and an in-depth analysis of the methodological problems underlying a specific theme of construction productivity research, cross-country comparisons. The authors also propose a research agenda for advancing knowledge in cross-country productivity analysis.

This paper is a review article based on an in-depth critique of the existing literature. Mayer (2009) described the purpose of a review paper as to organize, synthesize, and evaluate the literature to identify patterns and trends, thereby identifying research gaps and recommending new research areas. Review articles are virtual gold mines for identifying significant gaps in the research, current debates, and ideas of where research might go next (University of Texas at Austin 2010). Therefore, review articles of good quality are frequently needed in the presence of the growing number of research papers and to examine the current state of existing publications on a certain topic (Batovski 2008). The past decade has witnessed the continuation of the same relentless research interest in productivity research (Yi and Chan 2014).

Concepts of Productivity Measurement

This section presents a review of productivity measurement concepts, which helps to understand some of the arguments subsequently in the text. International productivity comparisons for the industry differ in the level of aggregation in the data. The choice of the boundary of the production system (sector, company, project, activity, task) and the associated data depend on the purpose of the investigation (Chau and Walker 1988). For example, project data are most appropriate if the impact of design, procurement, or site management is the subject of the investigation. A lower level of aggregation enables a better identification of the drivers of productivity and permits the control of heterogeneity in construction output. A major drawback is a greater data collection requirement (Hwang and Soh 2013). It is therefore unsurprising that a lot of existing works rely on readily available official sectoral data. Before reviewing studies using aggregated sectoral data, it is important to establish an understanding of productivity measures.

Productivity is a measure of the efficiency with which the economy turns inputs, such as labor and capital, into output. Single-factor productivity measures relate just to one input factor, often labor or capital to an output measure, whereas total (multifactor) productivity measures take into account the combined impact of all inputs on output.

If the output of an industry is homogeneous, it could be measured in physical units, e.g., cubic meters. However, the construction industry's output is heterogeneous given the diverse nature of construction projects (such as housing, rail bridges, and refurbishing work), which makes it infeasible to aggregate the industry's output into one physical measurement unit. Therefore, market prices are used as weights instead, and these weights should ideally also capture quality differences. As will be discussed subsequently, particularly the aggregation and the use of prices as weights leads to a couple of complications that limit the robustness of international productivity comparisons at an industry level.

Average labor productivity (ALP) is a common measure that relates output to labor inputs. For example:

- Output per worker, which is simple to measure, but comparisons suffer from differences in the way labor is used across countries; and
- Output per hour worked adjusts for labor intensity and is the most commonly used academic measure of productivity.

These measures are commonly used and seem to be intuitive. However, there are some drawbacks of the previous ALP measure of productivity. Its main limitation is that as a single-factor measure it is not well suited to the analysis of productivity, which involves separately identifying the contributions of the determinants of productivity performance. Disentangling the international differences or increases in output per worker into its constituent components would provide valuable information on the underlying causes of variability in productivity performance. It is the latter that is of particular value to policy makers and industry.

Such an approach would require relating construction output (Y) through a production function (f) to the tangible and intangible inputs of the production process. For this exposition it is assumed that there are three variable inputs, labor (L), capital (K), and materials (M). Other influences are captured by the shift factor a

$$Y = af(L, K, M) \tag{1}$$

Assuming the constant returns to scale this production function can be rearranged to

$$Y/L = af(1, K/L, M/L) \tag{2}$$

i.e., Y/L or ALP depends on the capital and material intensities and on a. Productive efficiency is maximized by choosing the level and quality of all inputs that maximizes output. As can be seen in Eq. (2), a relatively high ALP could be achieved at the expense of efficiency because ALP increases as capital or material is substituted for labor. The industry with the higher capital and material intensity would have a higher ALP irrespective of whether its input mix was output maximizing (Lowe 1987).

The issue of materials intensity is addressed by correcting output measures for brought in materials and services, i.e., by using value added as output measure. By doing this, however, information is lost because the impact of materials intensity on productivity cannot be assessed. There is another measure that is somewhat more difficult to compute but addresses the weakness of ALP measures discussed previously, total factor productivity (TFP).

Using the previous production function, TFP can then be expressed as

$$\mathrm{TFP} = Y/f(L, K, M) \tag{3}$$

TFP measures how efficiently inputs such as capital, labor, and materials are used together and can be interpreted as a range of difficult to measure factors such as technology, organization, management, competition, and regulation. Essentially, TFP measures the increase in output that is not attributable to an increase in measurable tangible input such a labor, capital, and materials.

As can be seen in Eq. (2) there is a link between average labor productivity and TFP, where the latter can be interpreted as a determinant of labor productivity (Crawford and Vogl 2006). Further, Eq. (2) can be used to calculate the contributions of TFP and the measureable inputs to intercountry differences in labor productivity and to labor productivity growth.

In the following sections, the authors review work on international productivity comparisons of the construction industry. The reader, however, should not expect an international ranking of construction industries. This can be found, for example, in the Royal Commission into the Building and Construction Industry (2002) report. Nor should the reader expect revised industry level productivity estimates. Rather, the paper will give a very detailed and comprehensive account as to why any such productivity estimates or productivity rankings are unreliable and elaborates on the underlying methodological problems. The problems are identified by a detailed critique of productivity studies commissioned by the U.K. Department for Business Innovation and Skills (BIS), formerly the Department for Trade and Industry (DTI). These studies were triggered by the government need to benchmark the U.K. construction productivity performance with a view of informing policy makers on the underlying root causes of international productivity gaps. This in turn was supposed to help prioritize construction industry–specific interventions with the view to improve the industry's productivity performance.

Sectoral Productivity Studies Based on National Accounts

International organizations such as the Organization for Economic Cooperation and Development (OECD) and the EU and national governments have undertaken considerable efforts to develop sectoral data sets that have been extensively used for productivity analysis at an industry or sector level, e.g., EU KLEMS and OECD STAN. While these data sets can provide interesting insights into cross-country productivity comparison and some of the underlying causes of cross-country differences in productivity for sectors such as manufacturing, they still provide poor policy guidance for the construction industry (Sezer and Bröchner 2013).

The following discussion focuses on reviewing studies commissioned by the U.K. Department for BIS, formerly the DTI. The objective of these studies was to establish how the United Kingdom ranked in terms of productivity and to inform policy makers about some of the underlying causes of differences in productivity between countries. These studies were chosen because all the data and the applied methodology are well documented and the lessons that can be learned from these studies have not been widely populated in the literature. Further, the issues exemplified using these studies equally applies to other studies using industry-level data for productivity comparisons and can provide good guidance for further research.

Evidence on the United Kingdom's Relative Average Labor Productivity Performance

Two reports commissioned by the Department of BIS investigated the relative position—in terms of ALP and TFP—of the U.K. construction industry compared with France, Germany, and the United States (Blake et al. 2004; Ive et al. 2004). BIS also funded the compilation of a comprehensive sectoral data set, which also incorporated productivity estimates of the construction industry (Mason et al. 2008). In these studies construction is defined in accordance with the Standard Industrial Classification (SIC) codes and includes general construction and demolition work, civil engineering, new construction work, and repair and maintenance. This could be regarded as a narrow definition of the construction industry (Pearce 2003) as SIC 45 [Office for National Statistics (ONS) 2002] (in the 2003 version of the U.K. SIC Codes) does not capture professional construction services nor does it include the construction products industry (Briscoe 2006).

In Table 1 are some international ALP comparisons for the construction sector, which are calculated as value added per hour worked, where the United Kingdom is indexed as 100.

There seems to be consensus that the United States is doing better (in terms of ALP) than its European counterparts, although Ive et al. (2004) suggest that that there is little difference between France and the United States. Mason et al. (2008) put the United Kingdom somewhat ahead of Germany and France, whereas Blake et al. (2004) and Ive et al. (2004) suggest that France and Germany are ahead of the United Kingdom.

What may explain these differences and how robust are these rankings? Robust benchmarking would require that output figures and labor inputs are internationally comparable. First of all, point estimates of labor productivity do not take into account the cyclicality of productivity (Abbott and Carson 2012). For example, the German construction output had been contracting for a prolonged period following the reunification boom in the early 1990s. This had most likely been a drag on German labor productivity and would require some adjustments for the relative cyclical position of the respective construction industries (Blake et al. 2004).

The use of market prices as weights requires the conversion of output figures into a common currency. For conversion of output

Table 1. Average Labor Productivity Comparison

Country	Ive et al. (2004)	Blake et al. (2004)	Mason et al. (2008)
France	137	108	92
Germany	121	109	91
United Kingdom	100	100	100
United States	139	132	124

Note: Value added per hour worked, United Kingdom = 100; the output estimates in Blake et al. (2004) and Ive et al. (2004) were converted by purchasing power parity rates to 1999 U.S. dollars and show productivity figures for the years 2001 and 1999, respectively; the Mason et al. (2008) estimates show labor productivity figures for 2004 and output figures were converted to U.S. dollars by a 2002 construction purchasing power parity rate.

Table 2. Implied Exchange Rate of Construction PPPs (Data from Eurostat-OECD 2012; Oanda 2014)

Exchange rate type	France ($ per €)	Germany ($ per €)	United Kingdom ($ per £)
Construction PPP 2002	0.73	0.88	1.45
GDP-PPP 2002	1.11	1.04	1.64
Average spot 2004	1.24	1.24	1.83

(value added) to a common currency, the main source for intercountry price comparisons are the purchasing power parities (PPPs) produced by Eurostat and the OECD, and these were used for the conversion into U.S. dollars by the previously cited studies. PPPs are exchange rates that equate the price of a homogeneous product across countries.

That adjustment is made because this paper is interested in international differences in resource inputs that are needed to produce a homogenous product (output) and the relationship between output and input should only be affected by real factors and not by movements in the exchange rates.

The difference between the Ive et al. (2004) and Blake et al. (2004) estimates can largely be explained by the use of different exchange rates. Blake et al. (2004) used sector-specific PPPs, whereas Ive et al. (2004) used whole economy PPPs based on the GDP deflator. The effects of switching the exchange rate are particularly pronounced for France. The subsequent example demonstrates the effect in more detail using the estimates by Mason et al. (2008).

Table 2 shows the implied exchange rates of the construction PPPs that were taken from OECD and Eurostat and used by Mason et al. (2008) to convert construction output into US dollars. These are compared with the PPP rate based on the GDP deflator and the average spot rate of 2004. The magnitude of the differences in the exchange rates are concerning. In particular, the extent to which the French construction PPP deviates from the other exchange rates looks unreasonable.

Fig. 1 demonstrates the impact of the use of different exchange rates on the labor productivity estimates. Moving from the construction PPPs to a GDP deflator-based PPP rate lifts the French productivity performance above the United States and reduces the productivity lead of the United States relative to the United Kingdom and Germany. When using the average spot rate of 2004, the French lead is further accentuated and the United Kingdom's and Germany's gap vis-a-vis the United States is further reduced.

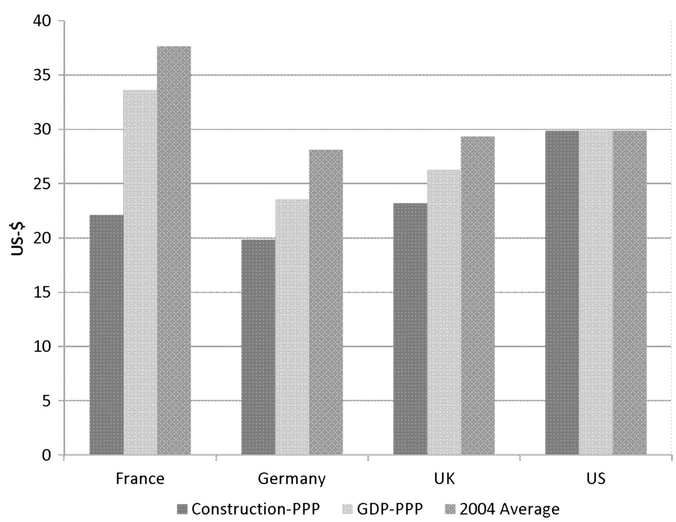

Fig. 1. Value added per hour worked in 2004 in dollars (data from Mason et al. 2008; Eurostat-OECD 2012; Oanda 2014)

While theoretically the concept of PPP is more appropriate for conversion than spot rates, there are problems surrounding how the construction PPPs are derived (Vermande and Mulligen 1999). Experts in different countries price a number of different, but fictitious, construction projects, ranging from different types of residential buildings, factory, and office buildings to civil engineering work, such as roads and bridges. These projects may be modified to accommodate different national circumstances and practices, such as regulation and building traditions. This ensures that the work is more representative of each country, but may reduce the comparability because the product may not be homogeneous any more.

These projects are priced on the basis of bills of quantities (Eurostat-OECD 2012). Whilst such an approach might be suitable for international price and costs comparisons, it is unsuitable for international productivity comparisons.

Bills of quantities already implicitly incorporate assumptions about productivity. To illustrate that point, assume that the bills of quantities only contained labor inputs.

If one calculated a PPP based on bills of quantities, the resulting exchange rate would be a labor productivity ratio equating labor productivity between countries. If these PPPs are then used to convert output figures into a common currency, countries with highly productive construction sectors would be penalized because their output figures would be biased downwards. That might explain why the French construction sector performs so poorly in these international comparisons, whereas anecdotal and case study evidence suggest that the French construction industry is very competitive (Edkins and Winch 1999a, b; Winch and Carr 2001). Hence international productivity comparisons for construction can be highly misleading until the value (or cost) conversion problem is resolved.

Also, there are other concerns that are hard to deal with. For example, it is unlikely that labor inputs are well measured in any country because of illegal immigration, the black economy, and difficulty of capturing self-employment. There are different approaches to the estimation of the sizes of the construction labor force, specifically its self-employed component. Broadly, there are household-based surveys and establishment-based surveys, and depending on the source estimates can differ substantially.

Household surveys may overreport employment because respondents confuse construction-related occupations with working for the construction industry and/or household surveys are better at picking up workers in the black economy and self-employment than are establishment-based surveys. Further, it needs to be investigated whether sources are chosen consistently across countries (Blake et al. 2004). Similar problems arise when trying to estimate the hours worked. Are things such as annual leave, illness, maternity leave, and overtime consistently estimated across countries? Establishment data tend not to capture the hours of the self-employed. Is regularly occurring overtime recorded as overtime? Comparisons of establishment data and household survey data from Germany suggest that the latter underreports overtime by as much as 25% (Richardson 2001).

In many ways cross-country comparisons of productivity levels across the whole construction industry are not comparing like for like because the composition of construction output differs so greatly between countries. Blake et al. (2004) show in their report the following differences in the mix of residential building, nonresidential building, and civil engineering in the four countries, which is reproduced in Table 3.

Table 3. Differences in the Mix of Residential Building, Nonresidential Building, and Civil Engineering (Data from Blake et al. 2004)

Country	Residential (%)	Nonresidential (%)	Civil engineering (%)
United States	46	36	18
United Kingdom	26	56	18
France	35	29	36
Germany	58	27	15

Given the relatively older stock of the built environment in England and France, there is also a substantial difference in the split between new build and repair and maintenance, as can be seen in Table 4.

Under a plausible assumption that productivity differs between these activities, the composition of output matters and is likely to affect the international comparison. A remedy to this problem would be to do an international comparison by type of work.

Such a disaggregation could potentially reveal interesting insights into the potential sources of productivity differences. Ive et al. (2004) provide productivity estimates at three-digit subsectors and for new construction and renovation and maintenance work. In the Eurostat data, construction output is divided into production, meaning new construction, and renovation and maintenance work. These are, however, measures of work done and not of value added. Using this measure it is suggested that labor productivity figures for new work are approximately 40% higher than for repair and maintenance work.

Ive et al. (2004) conclude that the data were too seriously flawed to be the basis for a subsectoral comparison of relative productivity levels. Further, the organization of the data in the 2003 SIC codes into 45 [Office for National Statistics (ONS) 2002]. 1 site preparation, 45.2 building of complete structures or parts thereof, 45.3 building installation, and 45.4 building completion was not seen as an useful starting point for an investigation of the difference between productivities in subsectors of construction, and the contribution these might make to overall levels of construction productivity. In this regard the SIC 2007 codes [Office for National Statistics (ONS) 2006] provide a much better classification of construction activities. They distinguish between 41 construction of buildings, 42 civil engineering, and 42 specialized construction activities, and the subdivision of SIC 41, for example, into commercial and domestic building provides a much better basis for productivity studies.

For example, one would expect the United Kingdom to exhibit a relatively high productivity in residential construction given the nature of the U.K. housing market and planning system. In the United Kingdom, house builders, the larger of which are also developers and land owners, will build the houses and then sell them. This contrasts, for example, with Germany and France where houses are more often built to demand. Thus, in the United Kingdom house building developments occur in much greater volume, which should lead to economies of scale and higher productivity (Barker 2004).This hypothesis could potentially be tested on the new SIC 2007 data.

Table 4. New Build versus Repair and Maintenance (Data from Blake et al. 2004)

Country	New build (%)	Repair and maintenance (%)
France	51	49
Germany	65	35
United Kingdom	52	48
United States	65	35

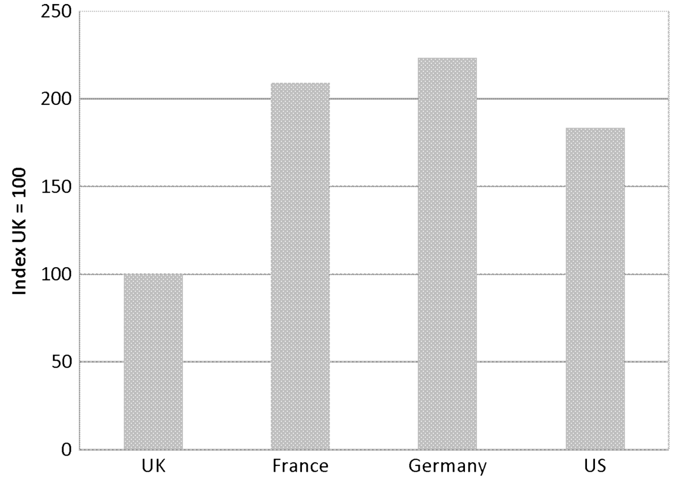

Fig. 2. Relative physical capital per hour worked (data from Mason et al. 2008)

Evidence on the United Kingdom's Relative Total Factor Productivity Performance

The usefulness of any productivity measurement framework for policy makers and industry practitioners alike crucially depends on the extent to which it enables the identification of the underlying drivers of productivity. This requirement necessitates an approach that involves formally describing the production process and explaining as much as possible the construction output in terms of the quantity and quality of inputs that are used to generate it. Economists tend to prefer estimating multifactor production functions for more in-depth productivity analysis.

Labor productivity is positively related to capital intensities and total factor productivity. This, however, increases data requirements further and necessitates the estimation of the industry's capital stock. Capital stocks figures are usually calculated using the perpetual inventory methods. Estimating capital stocks requires a long time series of investment plus assumptions on depreciation rates (Martin 2003). Depreciation rates should be industry specific and country specific, but it is often assumed that they are equal for identical industries across countries (Mason et al. 2008). The capital stocks estimates in each country are then converted with PPPs for investment goods to a common currency. The resultant figures provide estimates for the relative capital intensities of the production processes across countries. The capital stock estimates of Mason et al. (2008) in Fig. 2 suggest that construction workers in Germany, France, and the United States use more than two times more capital per hour worked than in the United Kingdom.

The magnitude of these country differences in capital intensities looks unreasonable and raises some concerns about the robustness of these estimates. One suspicion is that contractors in the United Kingdom make more use of rented construction and civil engineering machinery and equipment than the industries of the other countries. If that was the case capital services would be underrecorded for the United Kingdom because these services are bought from a service sector outside construction (SIC 71.32) [Office for National Statistics (ONS) 2002], i.e., not all capital services are recorded in SIC 45 construction. Clearly, here is the need to supplement the aggregate calculations with some more microlevel information about the industry (Baily and Solow 2001). A way of addressing the issue of fixed capital inputs to construction is by triangulation using a range of sources. These could include:

- Company accounts data on investment, depreciation, and hire payments.
- National account data SIC 45.5 "renting of construction or demolition equipment with operator" and SIC 71.32 "renting and operating leasing of construction and civil engineering machinery and equipment without operator," which also includes "renting of scaffolds and work platforms without erection and dismantling." It is these capital services in SIC 71.32 that are not accounted for in the previous capital stock estimates.
- A survey of firms to establish what asset lives they use for depreciation provisions and what lives they actually experience.

Capital inputs together with labor inputs, and in the study by Mason et al. (2008) also labor quality, are used for estimating relative total factor productivity levels. In order to explore the impact of labor quality differences on relative productivity performance, estimates of relative skill levels have been derived on the basis of educational attainments and mean wage levels analyzed by qualifications category. With regard to comparisons of labor force skills, research tends to divide the labor force into three or four categories of formal qualifications and then attempt to match those categories across countries [e.g., O'Mahony and de Boer (2002)]. This method is sensitive to the allocation of qualifications to the various categories. which is fraught with difficulty due to the differences in education and training institutions and formal qualifications systems in each country.

Mason et al. (2008) used a different methodology. Benchmarks on the highest qualifications category, where comparability across countries is suggested to be strongest, were established, and ratios of mean wages in other qualification groups relative to mean graduate wages within each country were calculated to derive a country-specific measure of labor quality.

There is a need for improved labor input measures. For example, labor quality (skills) will be dependent on a number of factors, such as qualifications, year of experience, age, hours of working on construction projects (e.g., by project type). The literature predominantly uses qualification levels as a proxy for skills, which is inaccurate because the skill level of the construction worker will be dependent on various factors as opposed to mere qualification attainment through training. Research suggests that training incidence is not synonymous with skills development and application. There is an issue of the transfer of learning to the workplace or project context, work organization, and leadership, which are all factors that influence skills deployment or utilization but are difficult to measure.

Table 5 suggests that the United Kingdom is leading Germany and France, but is somewhat behind the United States in terms of TFP.

As discussed previously, the estimation of TFP allows for the identification of factors that contribute to differences in average labor productivity relative to the United Kingdom, as shown in Table 1. Fig. 3 provides estimates of the contributions of intercountry differences in capital intensities, labor quality, and TFP to international gaps in average labor productivity. Given the substantially lower capital intensity of the U.K. sector, capital is a major drag on the United Kingdom's labor productivity performance relative to the comparator countries. A negative value in the chart points to a factor that drags down the United Kingdom's relative productivity performance.

In comparison with the European countries, the drag due to the United Kingdom's low capital intensity is, however, overcompensated by the United Kingdom's lead in total factor productivity. As shown previously, Germany has higher skills levels, which supports Germany's relative labor productivity performance, but the advantage in skills and capital intensity is insufficient to lift Germany's labor productivity above the U.K. level, given Germany's weak TFP performance. The productivity gap relative to the United States is explained by the higher capital intensity and better TFP performance of the U.S. construction industry, while the United Kingdom has a labor quality lead over the United States. This lead in labor quality is contradictory to the U.K. government discourse on skills policy, which claims that "U.K. skills base remains weak by international standards, holding back productivity, growth and social justice" (Leitch Review 2006, p. 3).

This brings in the question as to how robust are cross-country productivity comparisons? TFP measures are very sensitive to the quality of the data because TFP would pick up all the noise in the data. Thus, all the concerns already mentioned affect these estimates. Particularly, if the sector's use of capital services was underestimated, as suggested previously, the United Kingdom's relative TFP measure would be overestimated, i.e., an underreporting of the United Kingdom's capital intensity would be picked up by the term a in Eq. (2). That is because underreporting inputs would wrongly suggest that inputs were more efficiently used to produce a given amount of output. Any industry-level international comparison involving the calculation of TFP for construction would therefore need to revisit the capital stock estimates.

Furthermore, these TFP estimates are derived from a growth accounting framework that rests on a couple of restrictive assumptions such as perfect competition in output and factor markets and constant returns to scale. These are additional sources of potential problems that are also not so easily addressed. If firms are able to reap a premium due to the market power (unassociated with product quality), this will inflate TFP and there is a risk that economies of scale will show up as TFP, although they should in principle be captured by the explanatory variables if the production function is properly specified (Crawford and Vogl 2006). These problems,

Table 5. Relative TFP Levels

Country	O'Mahoney and de Boer (2002)	Blake et al. (2004)	Mason et al. (2008)
France	98	96	77
Germany	85	92	70
United Kingdom	100	100	100
United States	102	120	117

Note: United Kingdom = 100; the figures refer to the years 1999 (O'Mahoney and de Beoer 2002), 2001 (Blake et al. 2004), and 2002 (Mason et al. 2008).

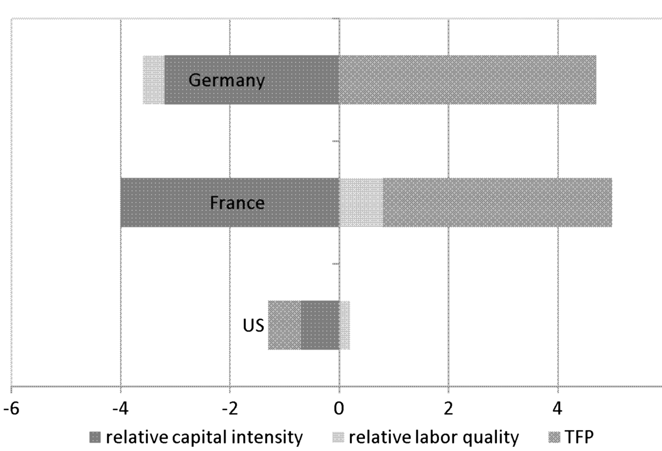

Fig. 3. Contributions to U.K. gap in ALP (proportions) (data from Mason et al. 2008)

however, seem to be minor issues compared with the data problems.

Summing up the previous discussion, any productivity ranking of countries at the industry level is highly problematic because these estimates do not compare like for like, data definitions and capture differ substantially across countries, and exchange rates used to convert output into a common currency are subject to substantial criticism. The identification of underlying productivity drivers is very crude and as a result the studies offer little guidance for industry and policy makers.

Comparisons of international differences in growth rates might be more robust because these are not affected by exchange rates and are less affected by differences in data definitions and capture.

Evidence on the Construction Industry's Productivity Growth

Time series studies based on national accounts statistics suggest that the industry's productivity growth has decelerated in many advanced economies and falls short of the productivity growth in the private sector. TFP growth has even become negative in some countries (Abdel-Wahab and Vogl 2011). As mentioned previously, TFP is associated with technological progress and improvements in management and organization. Has there been technological regress in construction? The puzzle of declining and even negative productivity and TFP growth is well documented in the literature and has been largely debated in the context of declining labor productivity in the North American construction industry [see, for example, Stokes (1981), Allen (1985), Rojas and Aramvareekul (2003), and Harper et al. (2010)].

Estimates of productivity growth are sensitive to the price indexes used for calculating a real output series. Calculating a real value-added time series requires double deflating. Gross output needs to be deflated by some output price and intermediate inputs need to be deflated by some input price. However, construction deflators are limited in scope and coverage (Ive et al. 2004). This problem has been discussed for some time and is still unresolved (Kaplan 1959; Sezer and Bröchner 2013).

Aggregate output deflators are often a mix of output prices and input cost indexes, with estimates based on bills of quantities [Office for National Statistics (ONS) 2012]. The use of input costs, however, may overstate the rise in construction output prices and hence understate real construction output and productivity. Assuming again that the bills of quantities would only include labor items, i.e., assuming that the output measure is based on labor costs only, an increase in labor costs would result in an equal rise in the output deflator. That would only be a fair assumption if labor productivity growth was zero (Harper et al. 2010). If, however, labor productivity increases, output prices should rise by less than labor costs, and hence using a cost measure as deflator output price inflation would be overstated and real output and productivity growth understated. This may to a large extent explain relative weak construction productivity growth (Allen 1985).

The composition of output may have changed across countries, e.g., towards more repair and maintenance as the age of the build environment increases. If the compositions of output shifts to sectors or activities with lower than average productivity, aggregate labor productivity will rise more slowly or could even become negative. Joregenson and Grilliches (1967) call this an error of aggregation. By aggregating data to an industry level, valuable information on the within-industry heterogeneity of outputs is lost. Again, a remedy to this problem would be to undertake an international comparison by type of work.

There is evidence in the literature that suggests there is a divergence in productivity trends between studies that work with aggregated data and those studies using activity-level data. For example, it was found for the United States (during the period 1976–1998) that an improvement in productivity performance at the activity level in the construction industry was not captured in the industry's overall productivity performance (Allmon et al. 2000; Goodrum et al. 2002), which underlies the need to briefly review alternative methodologies for cross-country productivity comparisons.

Alternative Methodologies of Comparing Construction Productivity Internationally

As previously mentioned, it is unsurprising that most existing works rely on readily available official industry data. While the use of microdata seem to be more appropriate in a project-based industry like construction because it enables to better control for the of heterogeneity in construction activity and to better identify performance drivers, data availability imposes a hurdle for such methodologies. The literature identifies four main types of productivity studies for cross-country comparative analysis, namely, (1) industry data from national accounts, i.e., the type of studies discussed previously, (2) pricing studies based on the experience of pricing experts, (3) case studies based on a small number of construction projects, and (4) studies based on company accounts (Edkins and Winch 1999a, b).

Pricing Studies

This methodology is flexible with regard to research design. Pricing studies base productivity estimates on quantitative and qualitative information on performance measures and resource inputs such as labor, material, and plant for projects based on specifications for a building, structure, activity, or task (Meikle 1990). This information is provided by experienced pricing professionals. Examples of this approach are the work by Xiao and Proverbs (2002a, b), who used the specification for a six-story concrete framed office building, and Proverbs et al. (1998a, b), who examined concrete placement operations.

The experts' views on the resource requirements for a given piece of construction work are likely to be based on their previous experience (Xiao and Proverbs 2002a) and/or pricing manuals that contain information on resource inputs and processes for specific types of construction work (Goodrum et al. 2002), which in turn are also likely to reflect previous experience. Pricing studies typically look at labor productivity only, often defined as productivity (unit) rates. A notable exception is Goodrum et al. (2002) and Goodrum and Hass (2002), who estimate a multifactor production process comprising labor and capital inputs and a measure for equipment technology.

There is a substantial amount of judgment involved in such studies, which makes it difficult to verify the robustness of their results. Christain and Hachey (1995) showed that this can result in substantial variation in productivity rates for well-specified tasks. To what extent this variation is due to differing judgments, different information sources, or past experience cannot be easily assessed. International studies also face the problem of the interpretation and pricing (quantification) of inputs by experts in one country unfamiliar with specifications from another country. Materials, methods of construction, and national standards and regulations can differ substantially between countries. Some flexibility of interpretation has to therefore be allowed (Eurostat-OECD 2012).

Furthermore, if outputs are measured in monetary terms, these studies also face the problem of deflation (Allmon et al. 2000) or the problem of converting output figures into a common currency [Bernard Williams Associates (BWA) 2006]. Pricing studies compare hypothetical buildings and thus may not give a complete picture of the real building process. While they may provide some idea on cost differences between countries, they are not well suited for identifying the underlying causes of differences. Typically these studies are therefore accompanied by surveys that ask experts for their views on the underlying causes of differences. Survey returns are analyzed in combination with existing qualitative and quantitative evidence taken from the literature (BWA 2006).

Case Studies

Case studies collect and analyze comprehensive project information on the quantity and quality of resource inputs, such as labor, plant and tools, management, and organization. Case studies draw on data from project accounts, timesheets, or on-site observations.

Studies at activity or task level can enable standardizing output across countries and measuring output in physical units. Sometimes only tasks common to projects are analyzed, such as the fitting of central heating or air conditioning units (Hawkins 1997) or the erection of concrete structures (Carr and Winch 1999). It is, however, somewhat problematic to infer from these observations an estimate for project or even industry performance.

Moreover, potentially important drivers of productivity such as (site) management and organization, design, procurement, and client expertise cannot be properly analyzed at such a highly disaggregated level, but could be analyzed at the project level. The major challenge here is then to identify internationally comparable projects. Examples for such studies are the Kodak polyethylene terephthalate (PET) plants built in the United Kingdom and the United States [National Economic Development Office (NEDO) 1990], the channel tunnel terminals in the United Kingdom and France (Edkins and Winch 1999a), and social housing projects in the United Kingdom and Germany (Clarke and Herrmann 2004).

While case studies enable researchers to make more informed hypotheses as to the determinants of labor productivity differences, testable cause and effect relationships are hard to establish, reflecting the considerable data requirements, and conclusions derived on the basis of few projects may not be representative of the country's industry. There is nonetheless likely to be a wealth of information in case studies that a systematic and comprehensive literature review could potentially reveal.

Company Accounts

Company accounts are another data source for international productivity comparisons that have not yet been fully explored. Studies based on company data could enable to control for the heterogeneity of output. The use of company data to investigate the productivity performance of the industry and its subsectors could provide further insights into subsectors, main contractors, and specialist contractors' relative productivity performance (Blake et al. 2004). This, however, requires identifying the principle activities of firms. Such studies would also face the deflation and currency conversion problems. Recently, Horta et al. (2013) applied a data envelopment analysis (DEA) to an international comparison based on accounting data. As all the data is in U.S. dollars and because only financial variables are used it is suggested that there is no need to deflate and to convert currencies. These financial input and output variables are, however, only loosely related to the productivity measures discussed previously.

The analysis is restricted to listed companies only. Given the large number of small-sized and medium-sized companies in the sector, the resulting conclusions may not be representative, bearing also in mind that these large contractors compete and act on a global scale. Unless company data are linked to data of potential performance drivers in construction, this approach will not identify the root cause of differences in performance.

Conclusions and Recommendations for Further Research

An improved understanding of the key drivers of the construction industry's productivity performance would help policy makers and industry to prioritize their policy and action. The recent efforts of international organization, national governments, and statistics offices in compiling industry-level data sets from national accounts data is to be applauded. However, data and methods well established for analyzing the performance of manufacturing sectors do not deliver robust evidence on construction performance.

A reason for the lack of robust evidence on construction productivity performance is the added complexity of a very heterogeneous project-based industry (Sezer and Bröchner 2013). While this paper suggests that new SIC codes and further construction-specific research efforts on deflators, conversion rates, labor inputs, and capital stock estimates could to some extent improve the robustness of international productivity comparisons, there are conceptual limitations to such an approach based on such highly aggregated data.

In order to analyze how construction output depends on its tangible and intangible inputs, the preferred scope is project level, which enables a more detailed comparison of support processes [e.g., management and organization, information technology (IT) systems, procurement, client involvement], auxiliary activities (e.g., innovation and design), inputs (hours worked and skills, material quality and prefabrication, capital equipment) and other factors such as climate and regulation.

In the national context, project-based performance indicators are collected and used for intracountry industry benchmarking in counties such as Australia, Brazil, Chile, Denmark, the United Kingdom, and the United States (Bakens et al. 2005; Costa et al. 2006). In the United Kingdom, key performance indicators (KPIs) were introduced in response to Egan's demand for a better evidence base for the improvement agenda. While most of the KPI measures are project based, the productivity KPI is company accounts based. This measure would thus also suffer from the problems discussed previously if used for international comparisons. Further, the existing KPIs are of limited use for establishing cause and effect relationships.

First, the company accounts-based performance measures do not directly relate to the project-based KPIs. Second, most KPIs measure report performance results (such as productivity, client and employee satisfaction, and defects) as opposed to providing information on the underlying drivers of performance. In order to establish cause and effect relationships, more leading performance measures would be needed (Beatham et al. 2004). In the terminology used previously, leading indicators are tangible and intangible inputs to the production process. These input measures can be used to predict performance and these offer industry and policymakers guidance on how to improve performance.

Other attempts for collecting project-based productivity data include the development of conceptual frameworks for productivity measurement, such as Park (2006). However, Dolage and Chan (2014) found that there is an absence of follow-up studies to investigate the validity of productivity measurement techniques and frameworks, and they argue that this is a striking feature of the existing literature. This suggests that any attempt for project-based productivity measurement without the endorsement and active participation of industry is likely to be unsuccessful.

Nonetheless, international productivity comparisons could build on the lessons learned from the various national initiatives worldwide. Ideally an international benchmarking club would facilitate the development of a project-based productivity measurement framework and a cross-country learning process. It becomes no surprise that the Conseil International de Batiment pour la Recherche, l'Etude et la Documentation (CIB) have set up a working commission (W117) entitled "Performance Measurement in Construction" with an overarching aim of disseminating research and practice of performance metrics in construction worldwide. The commission is going to achieve this through creating and disseminating a knowledge base of performance metrics worldwide (CIB 2013). However, the commission objective does not include an explicit statement for setting up a project-based common performance metrics framework for the purpose of cross-country productivity benchmarking.

The development of such a framework would first need to establish how to measure the quality and quantity of construction outputs and inputs and to ascertain the potential for collecting them across a number of projects and countries. In order to avoid any valuation problems and whenever feasible, measures should be in physical units. Data are likely to be spread across a range of diverse sources such as project managers, contractors, architects, clients, quantity surveyors, and company accounts. In addition, there should be considered within the context of the construction project life cycle (client brief, preconstruction, construction, and commissioning).

It would therefore be important to ascertain the willingness of the industry and clients to support such a project and to establish agreement on measures with potential data providers. In order to give incentives, it would also be important to demonstrate that such a measurement framework is beneficial to the industry and could be migrated to a management performance system (Costa et al. 2006). Any proposed measures should be seen as relevant to management in their daily work and as a means for continuous performance improvement on projects. Chan and Kaka (2003), in a questionnaire survey to 400 U.K. contractors, found that of the 77 respondents more than half do not monitor productivity levels at the project level. Therefore, it is important to collect project data without creating a burden on the data provider and requiring additional resources (time and money). This could be achieved by simplifying measurement methods, by only measuring important trades, and by standardizing the collection method (Hwang and Soh 2013).

In summary, the contribution of this paper has been to address a knowledge gap (and that is the absence of any review papers that discusses the methodological shortcomings of cross-country construction productivity measurement). While highlighting the shortcomings of existing studies on cross-country productivity comparisons, the adoption of a project-based approach for future studies is advocated. Developing a project-based international performance measurement framework is very ambitious, but the authors strongly believe that this should be the way forward in partnership with industry—perhaps through the establishment of an international benchmarking club.

The authors are finally proposing the following research agenda: review existing approaches for measuring productivity at the project level and propose a commonly agreed measurement framework in consultation with employers, which could be then piloted in actual projects and reviewed. Data can then be collected, evaluated, and the measurement framework reviewed where necessary. Any proposed project-level productivity measurement framework should (1) enable benchmarking the construction industry's productivity performance internationally, (2) enable the identification of the underlying drivers of productivity performance, and (3) provide guidance for industry and policy makers on how to improve performance.

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