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Labour productivity statistics: a reality check for the Norwegian Construction industry

Construction is one of the largest sectors that drive the global economy, yet it has failed to capture the necessary attention from the policy makers and investors. The existing construction statistics report the declining state of labour productivity. However, existing statistics often fail to reflect the true scope and economic impact of construction. They mainly account for on-site construction activities, but overlook the manufacturing of construction products and services in construction labour productivity statistics. The aim of the research is to investigate macro-economic labour productivity and identify the methodological problems inhibiting the effective measurement of construction labour productivity. The paper opted for academic literature review and a case study strategy for data collection. The findings reveal that many productive construction activities related to construction products and services are excluded from the construction labour productivity statistics. The results suggest that Norwegian construction labour productivity is not declining and is actually a productive industry in terms of value added per working hour. Although special reference has been made to Norwegian construction industry, the same approach holds validity at the international arena of construction statistics. The study offers insights and lessons to construction industries of other countries facing similar productivity related issues.

Keywords: construction statistics; labour productivity; productivity measurement

Subject classification codes: Construction management; Construction economics

1. Introduction and background

Productivity is amongst the most important and influential variables governing economic production activities (Singh, Motwani, & Kumar, 2000; Tangen, 2005). Despite the economic perspective of productivity, the world’s population has for the first time exceeded seven billion people and the construction industry is responsible for meeting the physical demands of the vast majority. Therefore, the construction sector’s productivity, both socially and economically, will be important to achieve resource efficiency in order to meet the sustainable development goals. As productivity is an important factor in social prosperity and sustainability, productivity improvement has remained one of the top policy priorities in the European Union's (EU) Lisbon agenda.

Construction industry has persistently pursued the improvements on the labour productivity; one of the primary reasons in this pursuit has been the costs associated with labour. The labour costs account for 30-40 % of the total construction costs (McNally & Havers, 1967; McTague & Jergeas, 2002). One the other hand, the Organisation for Economic Co-operation and Development (OECD) encourages productivity measurements with a purpose to trace technological change, identify changes in the efficiency, recognize real cost savings in production, benchmark production processes for best practices and assess the living standards. Construction industry is in practice of using three common productivity indices; multi-factor productivity, labour productivity and capital productivity (RCBCI, 2002). Relating to the productivity measurements, this paper focuses on labour productivity, which is referred to as the real value added per hours worked by the (OECD, 2015).

Statistical databases, such as the Eurostat, European Union (EU) KLEMS, United Nations Statistical Commission (UNSC) and OECD provide and publish overall and cross-country productivity analysis. In light of the EU KLEMS statistical database, several EU KLEMS member countries are facing the challenge of declining construction labour productivity. A plethora of academic, for examples Egan (1998) and Latham (1994), have also indicated the decline of construction productivity. Therefore, improving construction labour productivity has been at the heart of national governments and construction industry's agenda leading to various strategic policy initiatives (Vogl & Abdel-Wahab, 2015). An understanding of construction labour productivity measurement is therefore essential for helping the policy makers and practitioners to take effective action. Thus, this research focuses on investigating the weaknesses in macro-economic construction labour productivity measurements.

The academic evidence suggests that construction productivity measurements at macro level and micro levels yield different results. The diverging trend indicates the weakness between the aggregate and activity level productivity measurements (Abdel-Wahab & Vogl, 2011; Paul M Goodrum, Haas, & Glover, 2002; Pearce, 2003). The evidence form the literature and labour productivity statistics form the Eurostat database generates ambiguity around the state of macro-economic labour productivity measurements.

Therefore, the aim of this paper is to conduct an in-depth exploration of macro-economic labour productivity measurements and indicate the methodological problems that may inhibit the construction labour productivity measurements. Despite the strategic importance of the construction industry, the attempts to capture its true scope have been rather incomplete (Squicciarini & Asikainen, 2011). The quality of construction industry statistics have caused dissatisfaction amongst the academic and professional community (Ruddock, 2008). One of the prime causes of falling construction industry statistics reliability is the incompleteness and narrowness of the statistical definition of construction sector (G. Briscoe, 2006; Pearce, 2003; Squicciarini & Asikainen, 2011). According to G. Briscoe (2006), the statistical definition of construction sector fails to capture the construction services and construction products in productivity analysis.

Using the data from the Norwegian construction industry, a case study is designed to explore the deviation in labour productivity results between the narrow statistical definition of construction sector and the wider definition of construction sector as proposed by (G. Briscoe, 2006; Pearce, 2003) to answer the question: is construction labour productivity really declining? In order to achieve this, the statistical classification of economic activities practiced in European community (NACE Rev. 2) was analysed to identify the economic activities of construction products and services outside the official statistical definition of construction. The labour productivity growth of construction products and services is integrated with the labour productivity statistics of construction sector to reach the conclusions. The approach does not require any changes in statistical principles or data generation and aggregation. Even though the Norwegian construction industry's data is used for this study, a similar approach holds validity with the EU KLEMS and Eurostat statistical databases. The study is not aimed at true valuation of the Norwegian construction industry rather it only collects the necessary evidence to determine if the Norwegian construction labour productivity is in real decline.

2. Construction Labour Productivity Statistics

Construction Labour Productivity statistics are the LP measurements commissioned by the national governments and international statistical organizations such as Eurostat and OECD. Statisticians relate productivity to the measure of efficiency of the production process and categorize that process as an 'activity' in which different production factors such as raw materials, capital and labour combine to create specific goods or services. According to OECD (2001), LP is only a partial reflection of the personal capacities of workers, but it reflects the efficiency with which labour is combined with other factors of production. However, productivity comparisons have a long history of questionable validity and reliability, both from practitioners and the academic community (Rojas & Aramvareekul, 2003; Teicholz, Goodrum, & Haas, 2001). In the context of construction LP, statistical discrepancies may depend upon; method of measurement, classification system, input data and output data.

2.1.Method of measurement

The EU KLEMS database provides a consistent structure to collect input and output data across different industries and between the variables for comparisons of productivity growth rooted within the neo-classical production theory (O'Mahony & Timmer, 2009). According to neo-classical economic theory presented by Tinbergen (1942) savings generate growth in capital input and population growth generates growth in labour input. However, the method of measurement depends on the purpose of the productivity analysis. Based on input and output, there are many possible ways in which the construction LP can be measured depending upon the level of measurement (Thomas et al., 1986). Edkins and Winch (1999) categorized three basic approaches to measuring productivity as macroeconomic, case and pricing studies, the choice of which is dependent upon many factors such as the level of aggregation, data source (input/output) and boundary of the production process (Chau & Walker, 1988).

Moreover, there are different types of productivity measurements such as multi-factor productivity and single-factor productivity. Terminologies differ in construction literature and terms are often used interchangeably, as ‘productivity’ with ‘efficiency’, ‘multi-factor productivity’ with ‘total-factor productivity’ and ‘single-factor productivity’ with ‘partial-factor productivity’. Multi-factor productivity is the ratio of output to the sum of multiple inputs associated with labour and capital, whereas single-factor productivity is the ratio of output to one input that is usually in the form of labour, capital or material (Tran & Tookey, 2011). Dolage and Chan (2013) pointed out the scarcity of academic publications focusing on multi-factor productivity in construction. The concept and indices for multi-factor productivity were developed in late 1940s by the National Bureau of Economic Research in the United States (De Valence & Abbott, 2015). The low volume of research on multi-factor productivity is generally associated with the complexity to accurately measure all the input resources consumed to achieve the output. However, the work of Goodrum et al., (2002, 2009) on multi-factor productivity is of high relevance where he measured technological productivity of construction in relation with change in material technology (P. M. Goodrum, Zhai, & Yasin, 2009) and equipment technology (P. M. Goodrum & Haas, 2002)

From the review of existing literature, Vogl and Abdel-Wahab (2015) established single-factor productivity measurement such as output per working hours adjusted for labour intensity is the most common productivity measurement method used by the researchers. The LP outputs can be based on gross output or the value added concept (Tookey, 2011). Although both multi-factor and single-factor productivity measurement methods have limitations, Janssen and McLoughlin (2008) distinguished that single-factor productivity can be measured with reasonable reliability.

Multi-factor productivity is beneficial in the setting where micro-macro links are established for analysis, such as one industry’s contribution to economic productivity growth and living standards (Pilat & Schreyer, 2002). The major drawback of multi-factor productivity is activated when the value added is double-deflated with a fixed weight Laspeyres index causing conceptual and empirical drawbacks of the concept (Pilat & Schreyer, 2002). However, muti-factor productivity does provide the cross industrial ease of aggregation. Considering the limitations of methods and scope of queries, this research focuses on single-factor productivity based on the value added concept.

2.2.Classification system

The Eurostat database has largely been constructed on the basis of data from the National Statistical Institutes (NSI's) and processed according to harmonized procedures. The procedures are developed to ensure international comparability (O'Mahony & Timmer, 2009). Industrial classifications and definitions of the industrial sectors are harmonized for the statistical standards; NACE practiced in the European community, North American industrial classification system (NAICS) in the US, Canada and Mexico, International Standard Classification System (ISIC) developed by United Nations (UN) and Standard Industrial Classification adapted in the UK. The revised edition of NACE (NACE Rev. 2) has designated section `F` for construction, which contains 25 sub-classes, 23 classes, 9 groups and 3 divisions (see Table 1). The NACE Rev. 2 classification criterion is based on;

1. The production units classified under the same class must produce a significant share of total national production for group categorization.
2. The production units in the sub-classes should achieve maximum homogeneity in relation to product's nature and field of utilization.

NACE Rev. 2 classifies business establishments based upon the principal economic activity (G. Briscoe, 2006). The principal economic activity is the most important activity of the business establishment. Academics (G. Briscoe, 2006; Pearce, 2003) have argued that construction statistics fail to catch a substantial portion of construction activity from the organizations, because the organization's principal business activity is registered under classification other than construction in the national register.

Construction affects multiple industrial sectors, both directly and indirectly. Many organizations are involved in construction work, but their main business activity may not be construction. G. Briscoe (2006) indicated this problem in organizations such as health authorities, educational establishments, private-sector utilities and some transport undertakings which carry out a significant amount of construction work, but fail to distinct it from the principal business activity. Moreover, modern organizations have attained service complexities in multiple sectors and seek reclassifications to their premier industrial sectors. G. Briscoe (2006) associated such switching behaviours of large organizations to impair reliability and cause discontinuity in the construction time-series.

[Table 1 near here]

A detailed examination of Table 1 reveals that it mainly incorporates the on-site construction activities, i.e., the physical assembly of construction and maintenance activities performed at the construction site. Pearce (2003) raised the issue of definition of the construction sector and termed it as a narrow definition. Pearce (2003) associated the narrow definition of construction to the physical assembly and maintenance of dwellings, buildings and infrastructure, whereas in his broader definition of construction, he tries to capture the full scale of construction from off-site construction activities relating to products and services to the on-site construction activities associated with physical assembly. The report developed by Pearce (2003) stirred up debate in the academic community on whether the construction should be assessed based on the narrow definition provided in Table 1, or should it be reflected upon the true spectrum of construction. Several researchers debated upon the narrow definition of construction and tried to capture the full extent of construction activity including the peripheral industries that support the construction activity (G. H. Briscoe, 2006; Jewell & Flanagan, 2012; Squicciarini & Asikainen, 2011; Vogl & Abdel-Wahab, 2015).

Briscoe (2006) indicated that the most prominent gap is the NACE Rev. 2's failure to capture professional construction services and the construction products industry. Both of the gaps are related to off-site construction. Therefore, off-site construction is a major factor in the improvement of construction processes and site procedures (Taylor, 2010). This suggests that off-site construction factor is of significant value and cannot be ignored in construction LP calculations. The mining, manufacturing and service sector work in collaboration towards the buildability of on-site construction, where buildability is the most significant factor that influences the construction LP (Jarkas, 2015). The off-site construction industry has a two-dimensional fragmented nature in terms of entities and processes (Alashwal & Fong, 2015). This refers to tangible construction elements that are prefabricated off-site and the knowledge-based solutions and expertise for the design and construction of the projects as construction processes. The weaknesses associated with these off-site construction products and services are discussed below.

2.2.1. Construction Products

Construction products are tangible entities associated with the off-site construction industry. In this model, concrete modules can be produced in a factory and transported to the construction site for assembly (off-site) or can be cast on the construction site with the help of formwork (on-site) (Eastman & Sacks, 2008). The same applies to the possibility of producing many other construction elements such as façades, light steel frames and timber frames. A number of researchers (Ashworth & Hogg, 2014; Fawcett, Allison, & Corner, 2005; Gibb & Isack, 2003) have encouraged off-site construction practices in order to improve the productivity of the on-site construction. According to Eastman and Sacks (2008), the categorization of on-site and off-site construction activities can lead to a serious omission of many important productivity-enhancing innovations in construction, which is the dilemma the construction sector is facing today. Off-site production activities such as the production of prefabricated elements, modules and building materials are classified under the manufacturing section in NACE Rev. 2, which means that a major portion of construction entities are represented in manufacturing industry statistics.

2.2.2. Construction Services

Construction services are the knowledge based processes and strategies for construction processes which influence the buildability of on-site construction and ranges over a variety of services from architects, technical services, whole sale and retail services of construction material, employment activities and renting and leasing of construction equipment. Technology improvements have dramatically changed the processes and quality of construction (P. M. Goodrum et al., 2009). Architects, design engineers, draughtsmen and construction managers have benefited a great deal from information technology (IT) in the last decade. Furthermore, different services from other industrial sectors are making their way into construction, for example employment activities where the entire labour contribution or a part of it is rented from the third party and the same is the case for renting and leasing of construction equipment. The new breed of construction organizations based on Public Private Partnership (PPP) projects are on the rise and the narrow definition of construction makes it virtually impossible for all these initiatives to register the construction activity in the construction statistics (G. Briscoe, 2006). Construction design services determine the on-site buildability and are responsible for design rationalization, which is minimization of the amount of material, sizes, components or sub-assemblies (Jarkas, 2015).

The service sector has an influential role in any national economy (Jewell & Flanagan, 2012) and accounts for 73% of the United Kingdom’s output (Office for

National Statistics (ONS), 2010). Construction services have seen growth similar to the global service sector, which is responsible for one-fifth of worldwide trade in the balance of payments (United Nations UN, 2010). However, construction services are ignored in construction LP statistics.

2.3. Input data

Human interventions are widely measured in hours for construction LP research (Hanna, Chang, Sullivan, & Lackney, 2008; Thomas & Yiakoumis, 1987). G. H. Briscoe (2006) terms labour input in number of workers employed as a crude measure and recommends labour input in working hours as a more refined measure. NACE Rev. 2. only consider the working hours spent on the construction site by the workers as an input to construction LP. Calculating the working hours for labour is itself tricky due to various factors of data aggregation. Moreover NACE Rev. 2 distinguishes between workers directly employed in the construction process and other employees supporting the construction process. The distinction excludes hired labour and the employees of subcontractors from the construction LP statistics, despite being a major part of modern day construction. NACE Rev. 2 do compromise seasonal adjustments to the data and take into account temporary employees, apprentices, holidays and sick leave data. According to Wang (1999), the exercise of capturing working hours data is often affected by factors like technology, government regulations, weather, unions, economic conditions, management and internal environment issues.

2.4. Output data

The output or product of the construction industry is heterogeneous due to the diverse nature of construction projects and objectives and it varies from roads and bridges to dams and housing (Vogl & Abdel-Wahab, 2015). The diverse outputs from the construction processes and sub-processes are both tangible and nontangible (Pekuri, Haapasalo, & Herrala, 2011). This makes it difficult to measure construction output in physical units e.g., cubic meters. To counter such heterogeneity, outputs are measured in terms of holistic measures such as gross or value added (net output). Value added is the value created by the production, which is the value of outputs minus the value of both immediate consumption and consumption of fixed capital. Immediate consumption is documented by the purchaser price, which is the price the purchaser has paid for the product or service.

The value added at constant prices is the concept applied by economists for graphical presentation of a value added over time line. Statistical standards publish value added in terms of basic prices, which is the net amount entitled for the producer, i.e., the amount minus government taxes with the addition of any subsidies from the government for the particular product as a production or sale consequence. Comparison is a common purpose of productivity measurement (Chau & Walker, 1988). To represent productivity, data over a time series for historical comparisons requires a price reference for a certain reference year. Statisticians establish links from the value of the reference year by the annual percentage change in volume from year to year in each case. The change in volume remains the same from year to year but for a constant price, and the prices are subject to deflators for the comparisons. Links are established at both the detailed and aggregate levels, where the aggregate values deviate from the detailed values over longer periods of time, and the deviation is then adjusted by constant price estimates from the prices of the base year.

3. Research methodology

The theoretical footings of construction LP measurements in construction statistics are inspired by the work of Pearce (2003), G. H. Briscoe (2006), Squicciarini and Asikainen

(2011), Jewell and Flanagan (2012) and Vogl and Abdel-Wahab (2015). The reference lists from the inspired authors were trailed to find the limitations of the statistical classifications and LP measurements. Scopus and the Norwegian library database (ORIA), Google scholar were explored with research function of ‘labour productivity’, ‘labour productivity’, ‘workers productivity’, craftsmen’s productivity’ and ‘construction statistics’. The search string revealed 320 publications on SCOPUS search engine. The research results from the search engines along with trailing back the reference lists of the above authors, resulted in a final selection of the literature. Research theme of ‘construction labour productivity’ was developed with the help a final of 68 relevant academic publications were selected to gather the theory around the problem.

The theoretical analysis clarified the muddled picture of the classification of the construction sector and construction LP measurements by statisticians. The theoretical generalizations served as a departure point towards constructive and participatory research philosophies. Creswell (2013) highlighted that social interaction and multiple participants meaning is the essence of the constructivist philosophy of knowledge generation. The research study engaged an expert team with three representatives from the Statistics Norway with macroeconomic and statistical expertise, one industry representative from the EBA* to present their reservations about the current Statistics Norway’s construction LP measurement practices, and an academic research group of six researchers (from SINTEF* and NTNU*) to find weaknesses in the Statistics Norway construction LP measurements. The expert group was engaged three times in a monthly workshop at the office of Federation of Norwegian Construction Industries to reflect to the Norwegian construction LP statistics. Inspired by Crotty (1998) and based on his social constructivism approach, the research consisted of open-ended research questions using qualitative research methods to engage participants in a broader discussion to develop deeper insights. The conclusions were reached with theoretical standpoints and reflections of the expert group on the academic literature, global statistical standards in practice, and modern construction practices.

The characteristics of sound empirical research, as described by Eisenhardt and Graebner (2007), begin with a strong literature grounding. As Azhar, Ahmad, and Sein (2009) indicated, there is a need for a research approach in construction management that synthesizes applied and basic research by creating scientific knowledge and solutions for practical problems. This study is a combination of qualitative and quantitative research methods, the academic evidence presented in this paper relates to the qualitative research, whereas the case study refers to the quantitative share of this study. Qualitative and quantitative research approaches represent the two ends of the research continuum (Yilmaz, 2013). To test the theory from the qualitative research, a case study was designed by the expert group to complete the research cycle.

3.1. Design of case study

It was established from the theoretical analysis that both on-site and off-site construction is vital parts of modern construction, which makes construction LP a sum of on-site and off-site LP. For this particular case study on Norwegian construction industry, off-site construction is approached with classification of construction products and services. The Norwegian construction industry was chosen in this study due to availability of the required data and other practical reasons including access. From here, the paper uses the word 'on-site construction' for the section F (construction) of NACE Rev. 2., whereas the term 'construction' will be used for the sum of on-site construction, construction products and services.

The case study is designed within the statistical limitations of Statistics Norway's statistical productivity data and the Norwegian National Accounts (NNA). Statistics Norway and NNA maintain the biggest and most credible statistical data set in Norway, and it is practically impossible to replicate such data for verification studies. Although the case study was designed with special reference to the Norwegian construction LP, the same approach is valid in the international arena of construction LP statistics as NACE Rev. 2 has developed standardised methods for international comparability of construction LP. However, the NACE Rev. 2 classification divided production activities into section, division, group and classes and subclasses. By scrutinising the production activities in the Statistics Norway business register, the production activities that supported on-site construction operations, but were not classified under the construction section were listed in a secondary set of activities. The secondary set of production activities was then discussed in a workshop comprising the expert group members and negotiated with Statistics Norway for the possibility of data segregation.

[Table 2 near here]

Some of the production activities from the secondary set such as activities related to mining of construction materials were marked out of scope because such activities have to go through multiple production process to reach the construction site and each production process may result in different value gains. The secondary set was then reduced to a primary set of production activities, as presented in Table 2. To incorporate business activities associated with the construction products, the expert group selected three production activities from the Norwegian business register; manufacture of wood products except furniture, manufacture of non-metallic mineral products, and manufacture of basic metals except machine and tools. Table 2 also embodies the activities that resulted in construction services with a similar exercise.

For the contribution of each production activity, a weightage factor was established from the year 2013 with the help of NNA`s supply-use-tables adjusted for balance of payments. Each activity in the primary set of Off-site Production Activities (OPA) was assigned a factor with which it contributed towards the on-site construction section F of NACE Rev. 2 (see Table 2). As prices fluctuate over time and might lead to unrealistic comparisons, all the past and future pricing values were indexed to the pricing index of 2013; pricing values for 2014 and 2015 were also forecasted based on year 2013. A fifteen year time span started from 2000 was selected due to the special considerations to the revisions of statistical standards and the global financial crisis.

Data categorization of the construction process activity ‘architectural and engineering activities’ for the construction industry was not possible in the body of national data, which led the group to make a conservative assumption of dividing the data on architectural and technical services in half, where one half represents support for construction and other half support for other industries such as oil and gas. LP for all the activities in 2000 was set as a benchmark to examine logical productivity trends of construction-supporting activities over the agreed time span of 15 years. Value added and working hour’s data for all industries in Norway, on-site construction and each OPA for the period 2000–2015 was requested from Statistics Norway. Value added data for the construction support activities was treated with the respective weightage factor (see Table 2) for its contribution towards on-site construction. For logical comparisons over the historical time series of 15 years, the value added data was indexed to Statistics Norway’s published price index of 2013 and calculated in terms of relative percentage increase or decrease in LP from the preceding year. LP values in the year 2000 were set as the datum and point of origin with a designated value of 100%.

[Figure 1-10 near here]

4. Results and Discussion

Construction industry, construction products and construction services vary from country to country. The laws and legal systems may also vary depending upon the work force, climatic conditions and cost of material and production processes. According to Whitley and Kristensen (1996), the construction industry of every nation is regulated and shaped by the national systems, which leave each national construction industry largely idiosyncratic. To explore the input (Value-added) – output (working hours) trends in Norway, the selected OPA`s were plotted relative to the value added by the activity and the working hours data with year 2000 as a datum and reference year of origin. The graphical representations of these relations are presented in Figures 1 to 9. As productivity increases by increasing output and decreasing the input in Figures 1 to 9, the diverging trend of value added-working hours reflect the increase in productivity of that activity, whereas converging trend reflects decrease in the LP of that activity.

The OPA's of 'Manufacture of basic metals except machine and tools', 'employment activities' and 'on-site construction' reflect a declining trend. The activities that have experienced real productivity gains are 'Wholesale trade excluding motor vehicle', 'Retail trade except for motor vehicles and motor cycles' and 'Rental and leasing'. These activities are constantly producing more value with a relatively constant supply of work force. Whereas some activities such as 'Manufacture of wood products except furniture' and 'Manufacture of non-metallic mineral products' went through some historical turbulent trends with varying output (value added) in relation to the input (working hours).

[Figure 11 near here]

The most noticeable are the trends in 'on-site construction', though it is a declining activity in terms of LP. The input and output data reflect a linear relation and stability. Such stable trend provides the researcher to roughly forecast the construction input or output. The value added and working hour's data for on-site construction is plotted in Figure 10. Apart from the turbulent times of global financial crisis, the LP trends of on-site construction have been linear with a stable growth. Figure 10 also presents the regression analysis for future prediction of on-site construction value in relation to the working hours.

The two major factors that affect the construction output significantly are the land and house prices (Tookey, 2011), given that construction is a labour intensive industry with major operations in the build area. The construction output might remain compromised in comparison to the other sectors such as manufacturing, mining or services. From the value added studies, Figure 11 reflects that around 41 to 50 % of value of construction in relation to on-site construction (F) is generated off-site. The sum of value is far greater to be ignored and not looked upon in the context of construction. Figure 11 also illustrates that value of off-site construction activities is coupled with on-site construction i.e. when the value addition of on-site construction declines the value addition of off-site construction activities declines with it. Through the years, the value gains have steadily shifted to the off-site construction and it peaked in 2011 to 2013 where 49% of total value of construction was generated off-site.

[Figure 12 near here]

In the valuation of the UK off-site construction sector, (Taylor, 2010) concluded that the true extent of off-site construction is underestimated and that the gross output is far greater than the former calculations. Figure 11 also illustrates that the value generation in Norwegian off-site construction activities have steadily increased to approximately 50% of the value of on-site construction, which is a conservative estimate as our selected set of off-site construction activities might not represent the full scale of off-site construction activities. G. H. Briscoe (2006) questions the reliability of the construction statistics and highlights that output data such as gross and value added data are no longer useful for understanding the changing nature of construction activity.

The weighted and indexed LP of off-site construction activities (OPA) along with on-site construction are graphically plotted in Figure 12 for the span of 15 years (2000–2015). The OPA's reflect the contribution towards the on-site construction from the Statistics Norway data. Figure 12 provides a unique LP comparison between the LP of on-site construction and OPA's. Considering the on-site LP over the years as a datum or line of reference reveals that LP in the supporting activities of construction employment and the manufacturing of basic metals (excluding machines and tools) declined even more than on-site construction, reflecting a continuous declining trend. However, all the other OPA's reflected a positive growth trend in LP, with rental and leasing activities surging to productivity gains of over two times that of construction LP. Compared with construction, the magnitude of these contrary differences in LP seems suspicious. One suspicion is that Norwegian contractors in practice might have increased the renting and leasing of civil engineering equipment and machinery, which would shift the value gains of the construction sector to the service sector. This is similar to the manufacturing of construction products and assemblies.

[Figure 13-14 near here]

LP trend between off-site construction (OPA) and on-site construction is illustrated in Figure 13, which highlights that the off-site construction activities have seen larger gains on LP whereas LP on-site has steadily declined over the years. To compare the LP of OPA's to that of Norwegian LP of all industries, an aggregate weighted sum of these activities was compared to the LP of all Norwegian industries combined. The results are presented in Figure 14. The graphical representation in Figure 14 reveals that the LP of OPA`s at all times from 2000 to 2015 remained higher than the LP of all Norwegian industries combined, except for the years of global financial crisis. Figure 14 also reflects the injustice done to the construction sector by the statistical classification of NACE Rev. 2, whereby the most labour-productive domains of construction are excluded from the construction LP measurements. Integrating the LP of OPA's into on-site construction (F) resulted in construction LP presented in Figure 15. The modified construction LP reflects that construction LP is not declining. Construction is actually a productive industry when it comes to labour utilization, though it might not be as productive as some other industries. The dip in LP from 2008 to 2011 reflects the global financial crisis, which had an impact on the construction industry. However, after 2011, the construction industry's LP seems to be in recovery mode and improving. A better definition of the construction sector would not even just attract more attention from researcher and decision makers but will also claim a central policy stage for national productivity (Squicciarini & Asikainen, 2011).

[Figure 15 near here]

The LP of on-site construction (F) in comparison to construction LP (F+OPA) is presented in Figure 15 along with the LP of all Norwegian industries. For construction LP measurement, the LP sum of all OPA's is combined with the on-site construction to examine the LP trends with the improved spectrum of construction industry. The perception exists that construction is a technologically stagnant industry as compared to other industries; however, this belief in declining construction productivity is based on a number of studies that used industrial and macroeconomic data (Goodrum et al., 2009), whereas many researchers also report anecdotal evidence that construction productivity has actually improved (Bernstein, 2003; Goodrum et al., 2002; Tuchman, 2004). The comparison graph in Figure 15 also falsifies the general assumption that construction is a declining industry in terms of LP. Although, construction LP might not be increasing with the LP rate of other industries such as manufacturing, construction LP might be stagnant but is definitely not declining. Historically the changes to the statistics were initiated by the government statisticians (G. H. Briscoe, 2006), ignoring the construction industry which was most likely to use these statistics. The failure to gauge the real productivity of the construction industry has exposed weaknesses in the statistical classification system. These weaknesses are not only taking their toll on the future growth potential of the largest industrial sector in the world, but also hampering investor confidence, which is a necessary contributing factor in the development of the construction sector (Fox & Skitmore, 2007).

5. Conclusions

The construction industry's productivity measurements seem to be a victim of the statistical classification system. International statistical standards contributing towards global comparability define construction works only as the physical assembly of construction components at the construction site. This definition is narrow and fails to capture the real productivity and magnitude of the construction sector. Instead of revamping the construction classification system, it is possible to address and improve the weaknesses of construction LP measurements from within the statistical data. This study has indicated two weak areas of construction LP; namely construction products and services. The LP data of these weaknesses was integrated into construction LP to investigate the LP of the construction industry. The study reflects that OPA's are significantly more labour-productive than the on-site construction itself. Not only OPA's currently have a higher LP, but their rate of productivity growth is higher than the overall productivity of all Norwegian mainland industries combined. There is clear evidence that the OPA's have seen great gains in LP during 2000 to 2015, and Norwegian construction LP is not declining. However, due to the statistical classification system, these activities, though directly a part of the construction process, are instead contributing to the productivity statistics of the manufacturing and service industries, which also raises questions about the LP results of other industry sectors.

Construction is still a labour-intensive industry that is complying with the ever-increasing physical demands of the world. A realty check found that criticism of the Norwegian construction LP is exaggerated. The reliability of the national statistics is losing credibility in the ranks of the Norwegian construction industry, with contrasting LP calculations from the Norwegian labour unions and contractor associations. Norwegian construction has been modernized by integrating modern technologies and practices. However, the statistical measurement system on the other hand is persisting with a non-representative and narrow definition of the industry, which excludes all the productivity gains of the construction industry from the published productivity statistics. A major part of on-site construction works is labour-intensive and cannot be modularized or standardized due to their complexity, yet only these on-site operations are reflected in the construction industry productivity statistics. It seems as if most of the advances and modernization in the construction industry undertaken to improve its productivity have only resulted in a negative representation in the Norwegian construction LP statistics. In order to maintain their credibility, the statistical standards need a better definition of construction sector that can capture the true scope of construction. The paper also reflects the possibility of generating more reliable LP calculations, while remaining within the existing body of statistical data and aggregation methods. A similar exercise in the EU KLEMS and Eurostat member countries would be beneficial for streamlining the international comparisons of construction labour productivity and reflecting the real state of construction industry to policy makers.

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Labour productivity statistics: a reality check for the Norwegian Construction industry

Construction is one of the largest sectors that drive the global economy, yet it has failed to capture the necessary attention from the policy makers and investors. The existing construction statistics report the declining state of labour productivity. However, existing statistics often fail to reflect the true scope and economic impact of construction. They mainly account for on-site construction activities, but overlook the manufacturing of construction products and services in construction labour productivity statistics. The aim of the research is to investigate macro-economic labour productivity and identify the methodological problems inhibiting the effective measurement of construction labour productivity. The paper opted for academic literature review and a case study strategy for data collection. The findings reveal that many productive construction activities related to construction products and services are excluded from the construction labour productivity statistics. The results suggest that Norwegian construction labour productivity is not declining and is actually a productive industry in terms of value added per working hour. Although special reference has been made to Norwegian construction industry, the same approach holds validity at the international arena of construction statistics. The study offers insights and lessons to construction industries of other countries facing similar productivity related issues.

Keywords: construction statistics; labour productivity; productivity measurement

Subject classification codes: Construction management; Construction economics

1. Introduction and background

Productivity is amongst the most important and influential variables governing economic production activities (Singh, Motwani, & Kumar, 2000; Tangen, 2005). Despite the economic perspective of productivity, the world's population has for the first time exceeded seven billion people and the construction industry is responsible for meeting the physical demands of the vast majority. Therefore, the construction sector's productivity, both socially and economically, will be important to achieve resource efficiency in order to meet the sustainable development goals. As productivity is an important factor in social prosperity and sustainability, productivity improvement has remained one of the top policy priorities in the European Union's (EU) Lisbon agenda.

Construction industry has persistently pursued the improvements on the labour productivity; one of the primary reasons in this pursuit has been the costs associated with labour. The labour costs account for 30-40 % of the total construction costs (McNally & Havers, 1967; McTague & Jergeas, 2002). One the other hand, the Organisation for Economic Co-operation and Development (OECD) encourages productivity measurements with a purpose to trace technological change, identify changes in the efficiency, recognize real cost savings in production, benchmark production processes for best practices and assess the living standards. Construction industry is in practice of using three common productivity indices; multi-factor productivity, labour productivity and capital productivity (RCBCI, 2002). Relating to the productivity measurements, this paper focuses on labour productivity, which is referred to as the real value added per hours worked by the (OECD, 2015).

Statistical databases, such as the Eurostat, European Union (EU) KLEMS, United Nations Statistical Commission (UNSC) and OECD provide and publish overall and cross-country productivity analysis. In light of the EU KLEMS statistical database, several EU KLEMS member countries are facing the challenge of declining construction labour productivity. A plethora of academic, for examples Egan (1998) and Latham (1994), have also indicated the decline of construction productivity. Therefore, improving construction labour productivity has been at the heart of national governments and construction industry's agenda leading to various strategic policy initiatives (Vogl & Abdel-Wahab, 2015). An understanding of construction labour productivity measurement is therefore essential for helping the policy makers and practitioners to take effective action. Thus, this research focuses on investigating the weaknesses in macro-economic construction labour productivity measurements.

The academic evidence suggests that construction productivity measurements at macro level and micro levels yield different results. The diverging trend indicates the weakness between the aggregate and activity level productivity measurements (Abdel-Wahab & Vogl, 2011; Paul M Goodrum, Haas, & Glover, 2002; Pearce, 2003). The evidence form the literature and labour productivity statistics form the Eurostat database generates ambiguity around the state of macro-economic labour productivity measurements.

Therefore, the aim of this paper is to conduct an in-depth exploration of macro-economic labour productivity measurements and indicate the methodological problems that may inhibit the construction labour productivity measurements. Despite the strategic importance of the construction industry, the attempts to capture its true scope have been rather incomplete (Squicciarini & Asikainen, 2011). The quality of construction industry statistics have caused dissatisfaction amongst the academic and professional community (Ruddock, 2008). One of the prime causes of falling construction industry statistics reliability is the incompleteness and narrowness of the statistical definition of construction sector (G. Briscoe, 2006; Pearce, 2003; Squicciarini & Asikainen, 2011). According to G. Briscoe (2006), the statistical definition of construction sector fails to capture the construction services and construction products in productivity analysis.

Using the data from the Norwegian construction industry, a case study is designed to explore the deviation in labour productivity results between the narrow statistical definition of construction sector and the wider definition of construction sector as proposed by (G. Briscoe, 2006; Pearce, 2003) to answer the question: is construction labour productivity really declining? In order to achieve this, the statistical classification of economic activities practiced in European community (NACE Rev. 2) was analysed to identify the economic activities of construction products and services outside the official statistical definition of construction. The labour productivity growth of construction products and services is integrated with the labour productivity statistics of construction sector to reach the conclusions. The approach does not require any changes in statistical principles or data generation and aggregation. Even though the Norwegian construction industry's data is used for this study, a similar approach holds validity with the EU KLEMS and Eurostat statistical databases. The study is not aimed at true valuation of the Norwegian construction industry rather it only collects the necessary evidence to determine if the Norwegian construction labour productivity is in real decline.

2. Construction Labour Productivity Statistics

Construction Labour Productivity statistics are the LP measurements commissioned by the national governments and international statistical organizations such as Eurostat and OECD. Statisticians relate productivity to the measure of efficiency of the production process and categorize that process as an 'activity' in which different production factors such as raw materials, capital and labour combine to create specific goods or services. According to OECD (2001), LP is only a partial reflection of the personal capacities of workers, but it reflects the efficiency with which labour is combined with other factors of production. However, productivity comparisons have a long history of questionable validity and reliability, both from practitioners and the academic community (Rojas & Aramvareekul, 2003; Teicholz, Goodrum, & Haas, 2001). In the context of construction LP, statistical discrepancies may depend upon; method of measurement, classification system, input data and output data.

2.1.Method of measurement

The EU KLEMS database provides a consistent structure to collect input and output data across different industries and between the variables for comparisons of productivity growth rooted within the neo-classical production theory (O'Mahony & Timmer, 2009). According to neo-classical economic theory presented by Tinbergen (1942) savings generate growth in capital input and population growth generates growth in labour input. However, the method of measurement depends on the purpose of the productivity analysis. Based on input and output, there are many possible ways in which the construction LP can be measured depending upon the level of measurement (Thomas et al., 1986). Edkins and Winch (1999) categorized three basic approaches to measuring productivity as macroeconomic, case and pricing studies, the choice of which is dependent upon many factors such as the level of aggregation, data source (input/output) and boundary of the production process (Chau & Walker, 1988).

Moreover, there are different types of productivity measurements such as multi-factor productivity and single-factor productivity. Terminologies differ in construction literature and terms are often used interchangeably, as ‘productivity’ with ‘efficiency’, ‘multi-factor productivity’ with ‘total-factor productivity’ and ‘single-factor productivity’ with ‘partial-factor productivity’. Multi-factor productivity is the ratio of output to the sum of multiple inputs associated with labour and capital, whereas single-factor productivity is the ratio of output to one input that is usually in the form of labour, capital or material (Tran & Tookey, 2011). Dolage and Chan (2013) pointed out the scarcity of academic publications focusing on multi-factor productivity in construction. The concept and indices for multi-factor productivity were developed in late 1940s by the National Bureau of Economic Research in the United States (De Valence & Abbott, 2015). The low volume of research on multi-factor productivity is generally associated with the complexity to accurately measure all the input resources consumed to achieve the output. However, the work of Goodrum et al., (2002, 2009) on multi-factor productivity is of high relevance where he measured technological productivity of construction in relation with change in material technology (P. M. Goodrum, Zhai, & Yasin, 2009) and equipment technology (P. M. Goodrum & Haas, 2002)

From the review of existing literature, Vogl and Abdel-Wahab (2015) established single-factor productivity measurement such as output per working hours adjusted for labour intensity is the most common productivity measurement method used by the researchers. The LP outputs can be based on gross output or the value added concept (Tookey, 2011). Although both multi-factor and single-factor productivity measurement methods have limitations, Janssen and McLoughlin (2008) distinguished that single-factor productivity can be measured with reasonable reliability.

Multi-factor productivity is beneficial in the setting where micro-macro links are established for analysis, such as one industry's contribution to economic productivity growth and living standards (Pilat & Schreyer, 2002). The major drawback of multi-factor productivity is activated when the value added is double-deflated with a fixed weight Laspeyres index causing conceptual and empirical drawbacks of the concept (Pilat & Schreyer, 2002). However, muti-factor productivity does provide the cross industrial ease of aggregation. Considering the limitations of methods and scope of queries, this research focuses on single-factor productivity based on the value added concept.

2.2.Classification system

The Eurostat database has largely been constructed on the basis of data from the National Statistical Institutes (NSI's) and processed according to harmonized procedures. The procedures are developed to ensure international comparability (O'Mahony & Timmer, 2009). Industrial classifications and definitions of the industrial sectors are harmonized for the statistical standards; NACE practiced in the European community, North American industrial classification system (NAICS) in the US, Canada and Mexico, International Standard Classification System (ISIC) developed by United Nations (UN) and Standard Industrial Classification adapted in the UK. The revised edition of NACE (NACE Rev. 2) has designated section `F` for construction, which contains 25 sub-classes, 23 classes, 9 groups and 3 divisions (see Table 1). The NACE Rev. 2 classification criterion is based on;

1. The production units classified under the same class must produce a significant share of total national production for group categorization.
2. The production units in the sub-classes should achieve maximum homogeneity in relation to product's nature and field of utilization.

NACE Rev. 2 classifies business establishments based upon the principal economic activity (G. Briscoe, 2006). The principal economic activity is the most important activity of the business establishment. Academics (G. Briscoe, 2006; Pearce, 2003) have argued that construction statistics fail to catch a substantial portion of construction activity from the organizations, because the organization's principal business activity is registered under classification other than construction in the national register.

Construction affects multiple industrial sectors, both directly and indirectly. Many organizations are involved in construction work, but their main business activity may not be construction. G. Briscoe (2006) indicated this problem in organizations such as health authorities, educational establishments, private-sector utilities and some transport undertakings which carry out a significant amount of construction work, but fail to distinct it from the principal business activity. Moreover, modern organizations have attained service complexities in multiple sectors and seek reclassifications to their premier industrial sectors. G. Briscoe (2006) associated such switching behaviours of large organizations to impair reliability and cause discontinuity in the construction time-series.

[Table 1 near here]

A detailed examination of Table 1 reveals that it mainly incorporates the on-site construction activities, i.e., the physical assembly of construction and maintenance activities performed at the construction site. Pearce (2003) raised the issue of definition of the construction sector and termed it as a narrow definition. Pearce (2003) associated the narrow definition of construction to the physical assembly and maintenance of dwellings, buildings and infrastructure, whereas in his broader definition of construction, he tries to capture the full scale of construction from off-site construction activities relating to products and services to the on-site construction activities associated with physical assembly. The report developed by Pearce (2003) stirred up debate in the academic community on whether the construction should be assessed based on the narrow definition provided in Table 1, or should it be reflected upon the true spectrum of construction. Several researchers debated upon the narrow definition of construction and tried to capture the full extent of construction activity including the peripheral industries that support the construction activity (G. H. Briscoe, 2006; Jewell & Flanagan, 2012; Squicciarini & Asikainen, 2011; Vogl & Abdel-Wahab, 2015).

Briscoe (2006) indicated that the most prominent gap is the NACE Rev. 2's failure to capture professional construction services and the construction products industry. Both of the gaps are related to off-site construction. Therefore, off-site construction is a major factor in the improvement of construction processes and site procedures (Taylor, 2010). This suggests that off-site construction factor is of significant value and cannot be ignored in construction LP calculations. The mining, manufacturing and service sector work in collaboration towards the buildability of on-site construction, where buildability is the most significant factor that influences the construction LP (Jarkas, 2015). The off-site construction industry has a two-dimensional fragmented nature in terms of entities and processes (Alashwal & Fong, 2015). This refers to tangible construction elements that are prefabricated off-site and the knowledge-based solutions and expertise for the design and construction of the projects as construction processes. The weaknesses associated with these off-site construction products and services are discussed below.

2.2.1. Construction Products

Construction products are tangible entities associated with the off-site construction industry. In this model, concrete modules can be produced in a factory and transported to the construction site for assembly (off-site) or can be cast on the construction site with the help of formwork (on-site) (Eastman & Sacks, 2008). The same applies to the possibility of producing many other construction elements such as façades, light steel frames and timber frames. A number of researchers (Ashworth & Hogg, 2014; Fawcett, Allison, & Corner, 2005; Gibb & Isack, 2003) have encouraged off-site construction practices in order to improve the productivity of the on-site construction. According to Eastman and Sacks (2008), the categorization of on-site and off-site construction activities can lead to a serious omission of many important productivity-enhancing innovations in construction, which is the dilemma the construction sector is facing today. Off-site production activities such as the production of prefabricated elements, modules and building materials are classified under the manufacturing section in NACE Rev. 2, which means that a major portion of construction entities are represented in manufacturing industry statistics.

2.2.2. Construction Services

Construction services are the knowledge based processes and strategies for construction processes which influence the buildability of on-site construction and ranges over a variety of services from architects, technical services, whole sale and retail services of construction material, employment activities and renting and leasing of construction equipment. Technology improvements have dramatically changed the processes and quality of construction (P. M. Goodrum et al., 2009). Architects, design engineers, draughtsmen and construction managers have benefited a great deal from information technology (IT) in the last decade. Furthermore, different services from other industrial sectors are making their way into construction, for example employment activities where the entire labour contribution or a part of it is rented from the third party and the same is the case for renting and leasing of construction equipment. The new breed of construction organizations based on Public Private Partnership (PPP) projects are on the rise and the narrow definition of construction makes it virtually impossible for all these initiatives to register the construction activity in the construction statistics (G. Briscoe, 2006). Construction design services determine the on-site buildability and are responsible for design rationalization, which is minimization of the amount of material, sizes, components or sub-assemblies (Jarkas, 2015).

The service sector has an influential role in any national economy (Jewell & Flanagan, 2012) and accounts for 73% of the United Kingdom’s output (Office for National Statistics (ONS), 2010). Construction services have seen growth similar to the global service sector, which is responsible for one-fifth of worldwide trade in the balance of payments (United Nations UN, 2010). However, construction services are ignored in construction LP statistics.

2.3. Input data

Human interventions are widely measured in hours for construction LP research (Hanna, Chang, Sullivan, & Lackney, 2008; Thomas & Yiakoumis, 1987). G. H. Briscoe (2006) terms labour input in number of workers employed as a crude measure and recommends labour input in working hours as a more refined measure. NACE Rev. 2. only consider the working hours spent on the construction site by the workers as an input to construction LP. Calculating the working hours for labour is itself tricky due to various factors of data aggregation. Moreover NACE Rev. 2 distinguishes between workers directly employed in the construction process and other employees supporting the construction process. The distinction excludes hired labour and the employees of subcontractors from the construction LP statistics, despite being a major part of modern day construction. NACE Rev. 2 do compromise seasonal adjustments to the data and take into account temporary employees, apprentices, holidays and sick leave data.

According to Wang (1999), the exercise of capturing working hours data is often affected by factors like technology, government regulations, weather, unions, economic conditions, management and internal environment issues.

2.4. Output data

The output or product of the construction industry is heterogeneous due to the diverse nature of construction projects and objectives and it varies from roads and bridges to dams and housing (Vogl & Abdel-Wahab, 2015). The diverse outputs from the construction processes and sub-processes are both tangible and nontangible (Pekuri, Haapasalo, & Herrala, 2011). This makes it difficult to measure construction output in physical units e.g., cubic meters. To counter such heterogeneity, outputs are measured in terms of holistic measures such as gross or value added (net output). Value added is the value created by the production, which is the value of outputs minus the value of both immediate consumption and consumption of fixed capital. Immediate consumption is documented by the purchaser price, which is the price the purchaser has paid for the product or service.

The value added at constant prices is the concept applied by economists for graphical presentation of a value added over time line. Statistical standards publish value added in terms of basic prices, which is the net amount entitled for the producer, i.e., the amount minus government taxes with the addition of any subsidies from the government for the particular product as a production or sale consequence. Comparison is a common purpose of productivity measurement (Chau & Walker, 1988). To represent productivity, data over a time series for historical comparisons requires a price reference for a certain reference year. Statisticians establish links from the value of the reference year by the annual percentage change in volume from year to year in each case. The change in volume remains the same from year to year but for a constant price, and the prices are subject to deflators for the comparisons. Links are established at both the detailed and aggregate levels, where the aggregate values deviate from the detailed values over longer periods of time, and the deviation is then adjusted by constant price estimates from the prices of the base year.

3. Research methodology

The theoretical footings of construction LP measurements in construction statistics are inspired by the work of Pearce (2003), G. H. Briscoe (2006), Squicciarini and Asikainen (2011), Jewell and Flanagan (2012) and Vogl and Abdel-Wahab (2015). The reference lists from the inspired authors were trailed to find the limitations of the statistical classifications and LP measurements. Scopus and the Norwegian library database (ORIA), Google scholar were explored with research function of 'labour productivity', 'labour productivity', 'workers productivity', craftsmen's productivity' and 'construction statistics'. The search string revealed 320 publications on SCOPUS search engine. The research results from the search engines along with trailing back the reference lists of the above authors, resulted in a final selection of the literature. Research theme of 'construction labour productivity' was developed with the help a final of 68 relevant academic publications were selected to gather the theory around the problem.

The theoretical analysis clarified the muddled picture of the classification of the construction sector and construction LP measurements by statisticians. The theoretical generalizations served as a departure point towards constructive and participatory research philosophies. Creswell (2013) highlighted that social interaction and multiple participants meaning is the essence of the constructivist philosophy of knowledge generation. The research study engaged an expert team with three representatives from the Statistics Norway with macroeconomic and statistical expertise, one industry representative from the EBA* to present their reservations about the current Statistics Norway's construction LP measurement practices, and an academic research group of six researchers (from SINTEF* and NTNU*) to find weaknesses in the Statistics Norway construction LP measurements. The expert group was engaged three times in a monthly workshop at the office of Federation of Norwegian Construction Industries to reflect to the Norwegian construction LP statistics. Inspired by Crotty (1998) and based on his social constructivism approach, the research consisted of open-ended research questions using qualitative research methods to engage participants in a broader discussion to develop deeper insights. The conclusions were reached with theoretical standpoints and reflections of the expert group on the academic literature, global statistical standards in practice, and modern construction practices.

The characteristics of sound empirical research, as described by Eisenhardt and Graebner (2007), begin with a strong literature grounding. As Azhar, Ahmad, and Sein (2009) indicated, there is a need for a research approach in construction management that synthesizes applied and basic research by creating scientific knowledge and solutions for practical problems. This study is a combination of qualitative and quantitative research methods, the academic evidence presented in this paper relates to the qualitative research, whereas the case study refers to the quantitative share of this study. Qualitative and quantitative research approaches represent the two ends of the research continuum (Yilmaz, 2013). To test the theory from the qualitative research, a case study was designed by the expert group to complete the research cycle.

3.1. Design of case study

It was established from the theoretical analysis that both on-site and off-site construction is vital parts of modern construction, which makes construction LP a sum of on-site and off-site LP. For this particular case study on Norwegian construction industry, off-site construction is approached with classification of construction products and services. The Norwegian construction industry was chosen in this study due to availability of the required data and other practical reasons including access. From here, the paper uses the word ‘on-site construction’ for the section F (construction) of NACE Rev. 2., whereas the term ‘construction’ will be used for the sum of on-site construction, construction products and services.

The case study is designed within the statistical limitations of Statistics Norway’s statistical productivity data and the Norwegian National Accounts (NNA). Statistics Norway and NNA maintain the biggest and most credible statistical data set in Norway, and it is practically impossible to replicate such data for verification studies. Although the case study was designed with special reference to the Norwegian construction LP, the same approach is valid in the international arena of construction LP statistics as NACE Rev. 2 has developed standardised methods for international comparability of construction LP. However, the NACE Rev. 2 classification divided production activities into section, division, group and classes and subclasses. By scrutinising the production activities in the Statistics Norway business register, the production activities that supported on-site construction operations, but were not classified under the construction section were listed in a secondary set of activities. The secondary set of production activities was then discussed in a workshop comprising the expert group members and negotiated with Statistics Norway for the possibility of data segregation.

[Table 2 near here]

Some of the production activities from the secondary set such as activities related to mining of construction materials were marked out of scope because such activities have to go through multiple production process to reach the construction site and each production process may result in different value gains. The secondary set was then reduced to a primary set of production activities, as presented in Table 2. To incorporate business activities associated with the construction products, the expert group selected three production activities from the Norwegian business register; manufacture of wood products except furniture, manufacture of non-metallic mineral products, and manufacture of basic metals except machine and tools. Table 2 also embodies the activities that resulted in construction services with a similar exercise.

For the contribution of each production activity, a weightage factor was established from the year 2013 with the help of NNA`s supply-use-tables adjusted for balance of payments. Each activity in the primary set of Off-site Production Activities (OPA) was assigned a factor with which it contributed towards the on-site construction section F of NACE Rev. 2 (see Table 2). As prices fluctuate over time and might lead to unrealistic comparisons, all the past and future pricing values were indexed to the pricing index of 2013; pricing values for 2014 and 2015 were also forecasted based on year 2013. A fifteen year time span started from 2000 was selected due to the special considerations to the revisions of statistical standards and the global financial crisis.

Data categorization of the construction process activity 'architectural and engineering activities' for the construction industry was not possible in the body of national data, which led the group to make a conservative assumption of dividing the data on architectural and technical services in half, where one half represents support for construction and other half support for other industries such as oil and gas. LP for all the activities in 2000 was set as a benchmark to examine logical productivity trends of construction-supporting activities over the agreed time span of 15 years. Value added and working hour's data for all industries in Norway, on-site construction and each

OPA for the period 2000–2015 was requested from Statistics Norway. Value added data for the construction support activities was treated with the respective weightage factor (see Table 2) for its contribution towards on-site construction. For logical comparisons over the historical time series of 15 years, the value added data was indexed to Statistics Norway's published price index of 2013 and calculated in terms of relative percentage increase or decrease in LP from the preceding year. LP values in the year 2000 were set as the datum and point of origin with a designated value of 100%.

[Figure 1-10 near here]

4. Results and Discussion

Construction industry, construction products and construction services vary from country to country. The laws and legal systems may also vary depending upon the work force, climatic conditions and cost of material and production processes. According to Whitley and Kristensen (1996), the construction industry of every nation is regulated and shaped by the national systems, which leave each national construction industry largely idiosyncratic. To explore the input (Value-added) – output (working hours) trends in Norway, the selected OPA`s were plotted relative to the value added by the activity and the working hours data with year 2000 as a datum and reference year of origin. The graphical representations of these relations are presented in Figures 1 to 9. As productivity increases by increasing output and decreasing the input in Figures 1 to 9, the diverging trend of value added-working hours reflect the increase in productivity of that activity, whereas converging trend reflects decrease in the LP of that activity.

The OPA's of 'Manufacture of basic metals except machine and tools', 'employment activities' and 'on-site construction' reflect a declining trend. The activities that have experienced real productivity gains are 'Wholesale trade excluding motor vehicle', 'Retail trade except for motor vehicles and motor cycles' and 'Rental and leasing'. These activities are constantly producing more value with a relatively constant supply of work force. Whereas some activities such as 'Manufacture of wood products except furniture' and 'Manufacture of non-metallic mineral products' went through some historical turbulent trends with varying output (value added) in relation to the input (working hours).

[Figure 11 near here]

The most noticeable are the trends in 'on-site construction', though it is a declining activity in terms of LP. The input and output data reflect a linear relation and stability. Such stable trend provides the researcher to roughly forecast the construction input or output. The value added and working hour's data for on-site construction is plotted in Figure 10. Apart from the turbulent times of global financial crisis, the LP trends of on-site construction have been linear with a stable growth. Figure 10 also presents the regression analysis for future prediction of on-site construction value in relation to the working hours.

The two major factors that affect the construction output significantly are the land and house prices (Tookey, 2011), given that construction is a labour intensive industry with major operations in the build area. The construction output might remain compromised in comparison to the other sectors such as manufacturing, mining or services. From the value added studies, Figure 11 reflects that around 41 to 50 % of value of construction in relation to on-site construction (F) is generated off-site. The sum of value is far greater to be ignored and not looked upon in the context of construction. Figure 11 also illustrates that value of off-site construction activities is coupled with on-site construction i.e. when the value addition of on-site construction declines the value addition of off-site construction activities declines with it. Through the years, the value gains have steadily shifted to the off-site construction and it peaked in 2011 to 2013 where 49% of total value of construction was generated off-site.

[Figure 12 near here]

In the valuation of the UK off-site construction sector, (Taylor, 2010) concluded that the true extent of off-site construction is underestimated and that the gross output is far greater than the former calculations. Figure 11 also illustrates that the value generation in Norwegian off-site construction activities have steadily increased to approximately 50% of the value of on-site construction, which is a conservative estimate as our selected set of off-site construction activities might not represent the full scale of off-site construction activities. G. H. Briscoe (2006) questions the reliability of the construction statistics and highlights that output data such as gross and value added data are no longer useful for understanding the changing nature of construction activity.

The weighted and indexed LP of off-site construction activities (OPA) along with on-site construction are graphically plotted in Figure 12 for the span of 15 years (2000–2015). The OPA’s reflect the contribution towards the on-site construction from the Statistics Norway data. Figure 12 provides a unique LP comparison between the LP of on-site construction and OPA’s. Considering the on-site LP over the years as a datum or line of reference reveals that LP in the supporting activities of construction employment and the manufacturing of basic metals (excluding machines and tools) declined even more than on-site construction, reflecting a continuous declining trend. However, all the other OPA’s reflected a positive growth trend in LP, with rental and leasing activities surging to productivity gains of over two times that of construction LP. Compared with construction, the magnitude of these contrary differences in LP seems suspicious. One suspicion is that Norwegian contractors in practice might have increased the renting and leasing of civil engineering equipment and machinery, which would shift the value gains of the construction sector to the service sector. This is similar to the manufacturing of construction products and assemblies.

[Figure 13-14 near here]

LP trend between off-site construction (OPA) and on-site construction is illustrated in Figure 13, which highlights that the off-site construction activities have seen larger gains on LP whereas LP on-site has steadily declined over the years. To compare the LP of OPA's to that of Norwegian LP of all industries, an aggregate weighted sum of these activities was compared to the LP of all Norwegian industries combined. The results are presented in Figure 14. The graphical representation in Figure 14 reveals that the LP of OPA`s at all times from 2000 to 2015 remained higher than the LP of all Norwegian industries combined, except for the years of global financial crisis. Figure 14 also reflects the injustice done to the construction sector by the statistical classification of NACE Rev. 2, whereby the most labour-productive domains of construction are excluded from the construction LP measurements. Integrating the LP of OPA's into on-site construction (F) resulted in construction LP presented in Figure 15. The modified construction LP reflects that construction LP is not declining. Construction is actually a productive industry when it comes to labour utilization, though it might not be as productive as some other industries. The dip in LP from 2008 to 2011 reflects the global financial crisis, which had an impact on the construction industry. However, after 2011, the construction industry's LP seems to be in recovery mode and improving. A better definition of the construction sector would not even just attract more attention from researcher and decision makers but will also claim a central policy stage for national productivity (Squicciarini & Asikainen, 2011).

[Figure 15 near here]

The LP of on-site construction (F) in comparison to construction LP (F+OPA) is presented in Figure 15 along with the LP of all Norwegian industries. For construction LP measurement, the LP sum of all OPA's is combined with the on-site construction to examine the LP trends with the improved spectrum of construction industry. The perception exists that construction is a technologically stagnant industry as compared to other industries; however, this belief in declining construction productivity is based on a number of studies that used industrial and macroeconomic data (Goodrum et al., 2009), whereas many researchers also report anecdotal evidence that construction productivity has actually improved (Bernstein, 2003; Goodrum et al., 2002; Tuchman, 2004). The comparison graph in Figure 15 also falsifies the general assumption that construction is a declining industry in terms of LP. Although, construction LP might not be increasing with the LP rate of other industries such as manufacturing, construction LP might be stagnant but is definitely not declining. Historically the changes to the statistics were initiated by the government statisticians (G. H. Briscoe, 2006), ignoring the construction industry which was most likely to use these statistics. The failure to gauge the real productivity of the construction industry has exposed weaknesses in the statistical classification system. These weaknesses are not only taking their toll on the future growth potential of the largest industrial sector in the world, but also hampering investor confidence, which is a necessary contributing factor in the development of the construction sector (Fox & Skitmore, 2007).

5. Conclusions

The construction industry's productivity measurements seem to be a victim of the statistical classification system. International statistical standards contributing towards global comparability define construction works only as the physical assembly of construction components at the construction site. This definition is narrow and fails to capture the real productivity and magnitude of the construction sector. Instead of revamping the construction classification system, it is possible to address and improve the weaknesses of construction LP measurements from within the statistical data. This study has indicated two weak areas of construction LP; namely construction products and services. The LP data of these weaknesses was integrated into construction LP to investigate the LP of the construction industry. The study reflects that OPA's are significantly more labour-productive than the on-site construction itself. Not only OPA's currently have a higher LP, but their rate of productivity growth is higher than the overall productivity of all Norwegian mainland industries combined. There is clear evidence that the OPA's have seen great gains in LP during 2000 to 2015, and Norwegian construction LP is not declining. However, due to the statistical classification system, these activities, though directly a part of the construction process, are instead contributing to the productivity statistics of the manufacturing and service industries, which also raises questions about the LP results of other industry sectors.

Construction is still a labour-intensive industry that is complying with the ever-increasing physical demands of the world. A realty check found that criticism of the Norwegian construction LP is exaggerated. The reliability of the national statistics is losing credibility in the ranks of the Norwegian construction industry, with contrasting LP calculations from the Norwegian labour unions and contractor associations. Norwegian construction has been modernized by integrating modern technologies and practices. However, the statistical measurement system on the other hand is persisting with a non-representative and narrow definition of the industry, which excludes all the productivity gains of the construction industry from the published productivity statistics. A major part of on-site construction works is labour-intensive and cannot be modularized or standardized due to their complexity, yet only these on-site operations are reflected in the construction industry productivity statistics. It seems as if most of the advances and modernization in the construction industry undertaken to improve its productivity have only resulted in a negative representation in the Norwegian construction LP statistics. In order to maintain their credibility, the statistical standards need a better definition of construction sector that can capture the true scope of construction. The paper also reflects the possibility of generating more reliable LP calculations, while remaining within the existing body of statistical data and aggregation methods. A similar exercise in the EU KLEMS and Eurostat member countries would be beneficial for streamlining the international comparisons of construction labour productivity and reflecting the real state of construction industry to policy makers.

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Table 1: Statistical Classification of the Construction Section (F) (NACE Rev. 2)

Group	Class	Description of class	Subclass and description
41.1		**Development of building projects**	
	41.10	Development of building projects	41.101.House building cooperative 41.109.Other develop/sale of real state
41.2		**Construction of buildings**	
	41.20	Construction of buildings	41.200.Construction of buildings
42.1		**Construction of roads and railways**	
	42.11	Construction of roads and motorways	42.110.Construction of roads and motorways
	42.12	Construction of railways etc.	42.120.Construction of railways etc.
	42.13	Construction of bridges and tunnels	42.130.Construction of bridges and tunnels
42.2		**Construction of utility projects**	
	42.21	Construction of utility projects for fluids	42.210.Construction of utility projects for fluids
	42.22	Construction for utility projects for electricity and telecommunications	42.220.Construction for utility projects for electricity and telecommunications
42.9		**Construction of other civil engineering projects**	
	42.91	Construction of water projects	42.910.Construction of water projects
	42.99	Construction of other civil engineering projects n.e.c.	42.990.Construction of other civil engineering projects n.e.c.
43.1		**Demolition and site preparation**	
	42.11	Demolition	42.110.Demolition
	42.12	Site preparation	42.120.Site preparation
	42.13	Test drilling and boring	42.130.Test drilling and boring
43.2		**Building Installation**	
	43.21	Electrical installation	43.210.Electrical installation
	43.22	Plumbing heat and air conditioning installation	43.221.Plumbing- and ventilation-install 43.222.Refrigeration-/heat pump install.
	43.29	Other construction installation	43.290.Other construction installation
43.3		**Building completion and finishing**	
	43.31	Plastering	43.310Plastering
	43.32	Joinery installation	43.320.Joinery installation
	43.33	Floor and wall covering	43.330.Floor and wall covering
	43.34	Painting and glazing	43.341.Painting 43.342.Glazing
	43.39	Other building completion and finish	43.390.Other building completion and finish
43.9		**Other special construction activities**	
	43.91	Roofing activities	43.911.Tinsmith work 43.919. Other erec. of roof cov./frames
	43.99	Other special construction activities	43.990.Other special construction activities

Table 1: Weightage factors for Off-site Production Activities (OPA)

	Statistical Challenges	**Weightage factor**	**Classification code**	**Off-site Production activities (OPA)**
1	Construction products	1.00	C16	Manufacture of wood products except furniture
		0.80	C23	Manufacture of non-metallic mineral products
		0.28	C24	Manufacture of basic metals except machine and tools
2	Construction services	0.50	M71	Architecture and engineering activities
		0.16	G46	Wholesale trade excluding motor vehicle
		0.07	G47	Retail trade except for motor vehicles and motor cycles
		0.19	N77	Rental and leasing
		0.20	N78	Employment activities

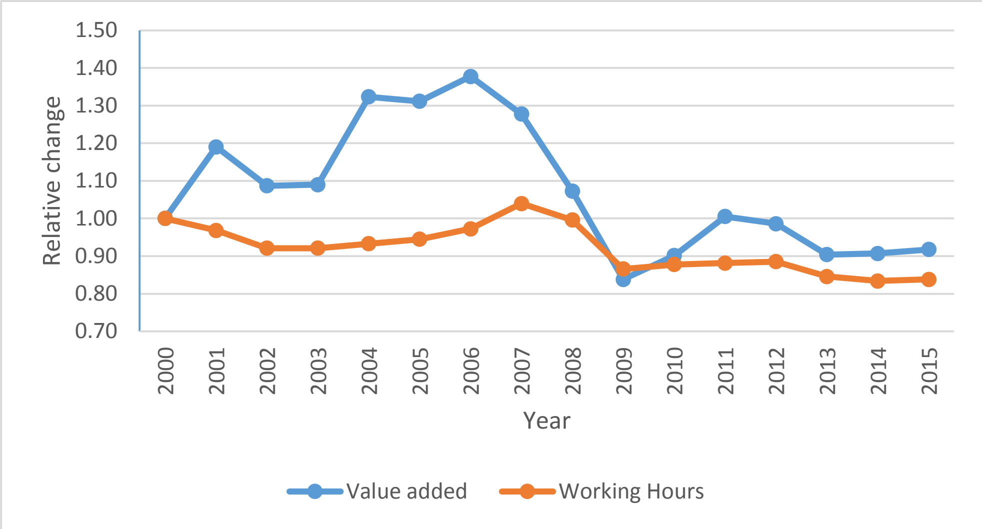

Figure 1: C16 relative value added and working hours

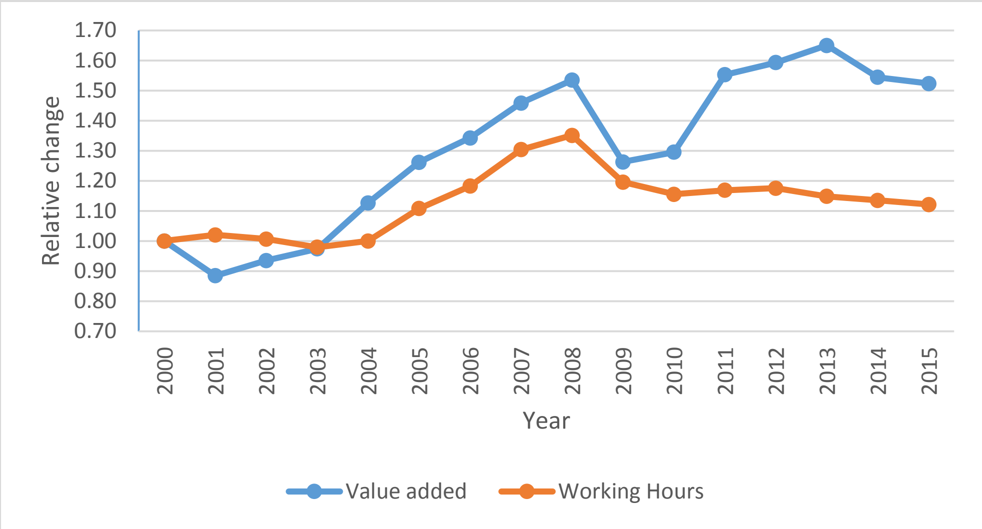

Figure 2: C23 relative value added and working hours

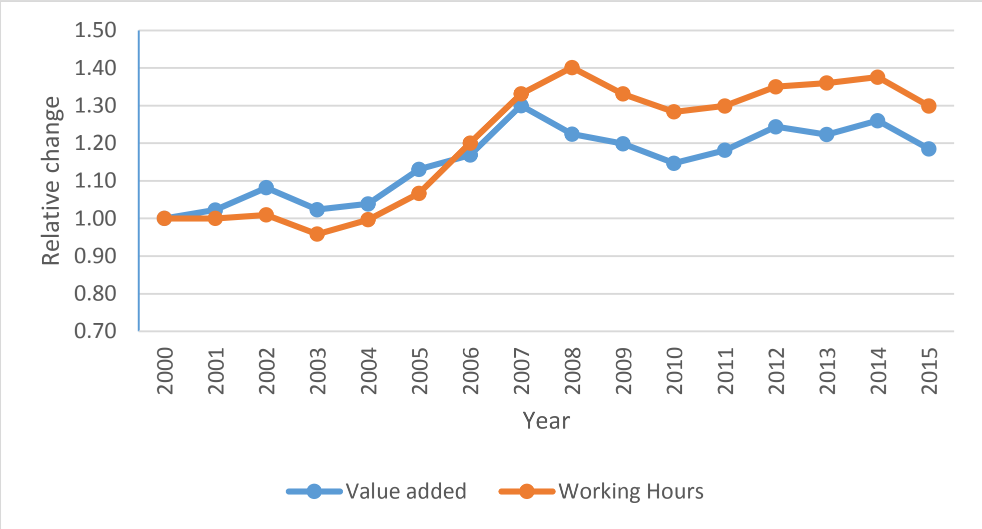

Figure 3: C24 relative value added and working hours

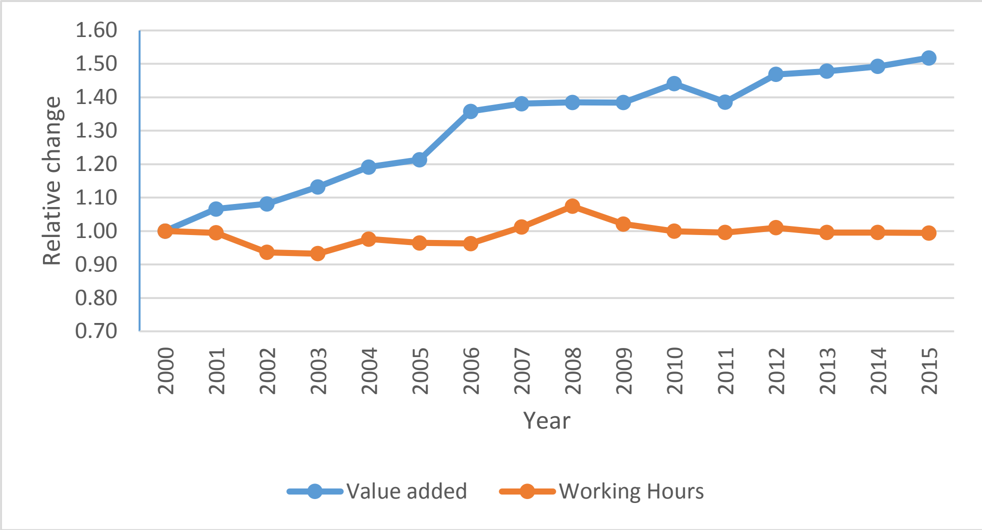

Figure 4: G46 relative value added and working hours

Figure

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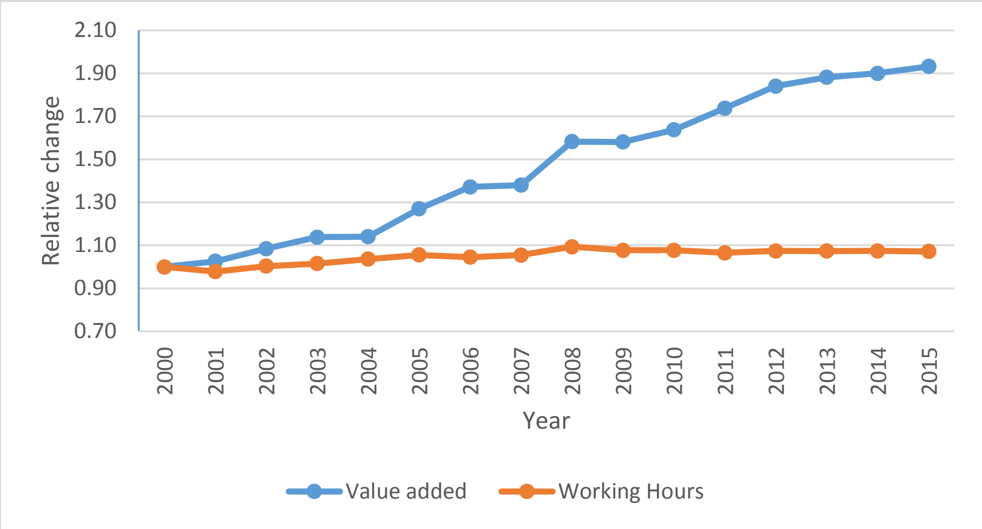

Figure 5: G47 relative value added and working hours

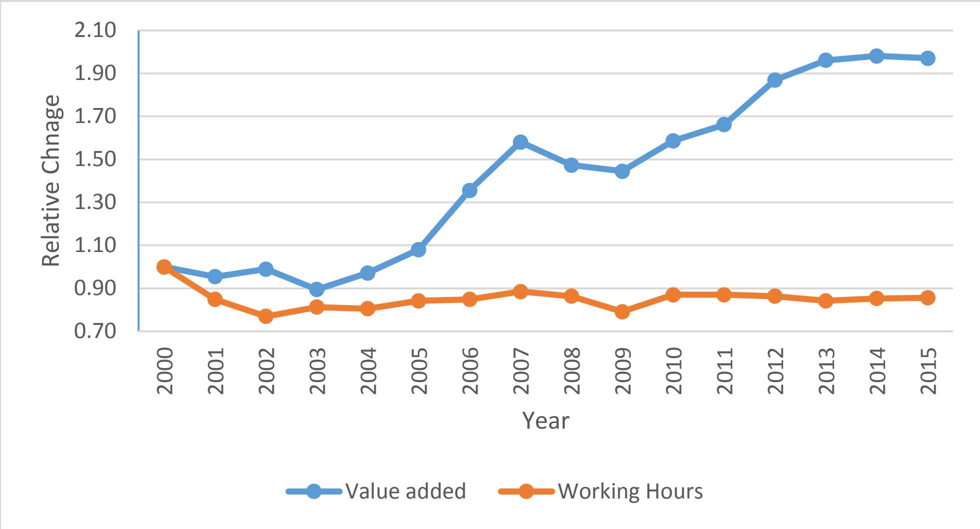

Figure 6: N77 relative value added and working hours

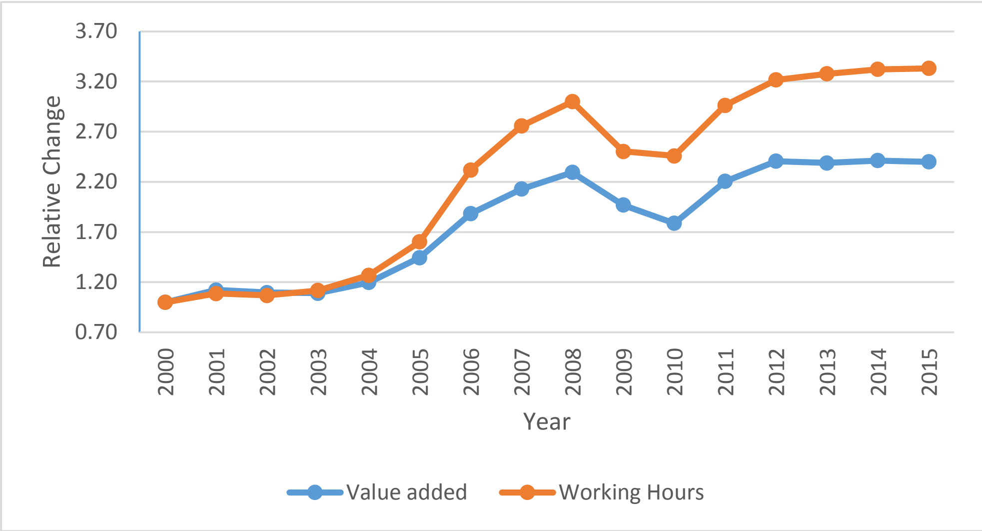

Figure 7: N78 relative value added and working hours

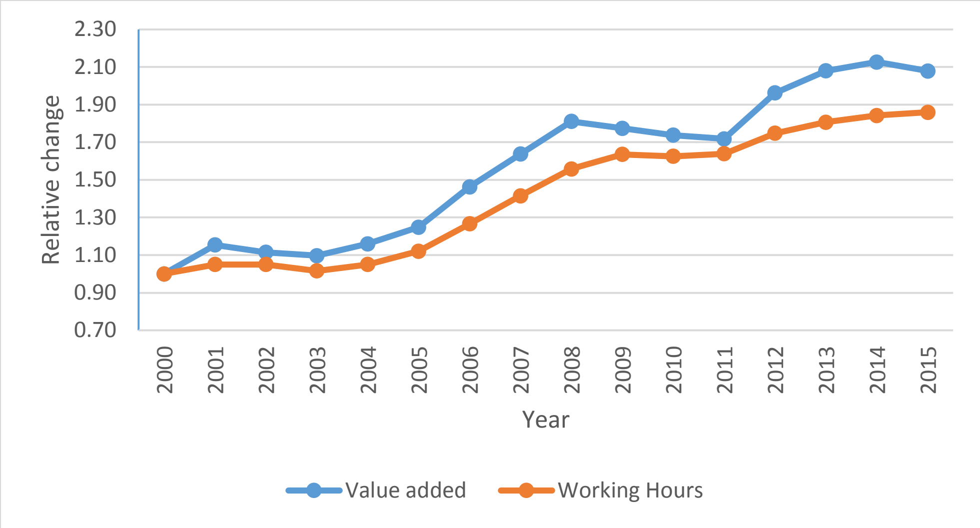

Figure 8: M71 relative value added and working hours

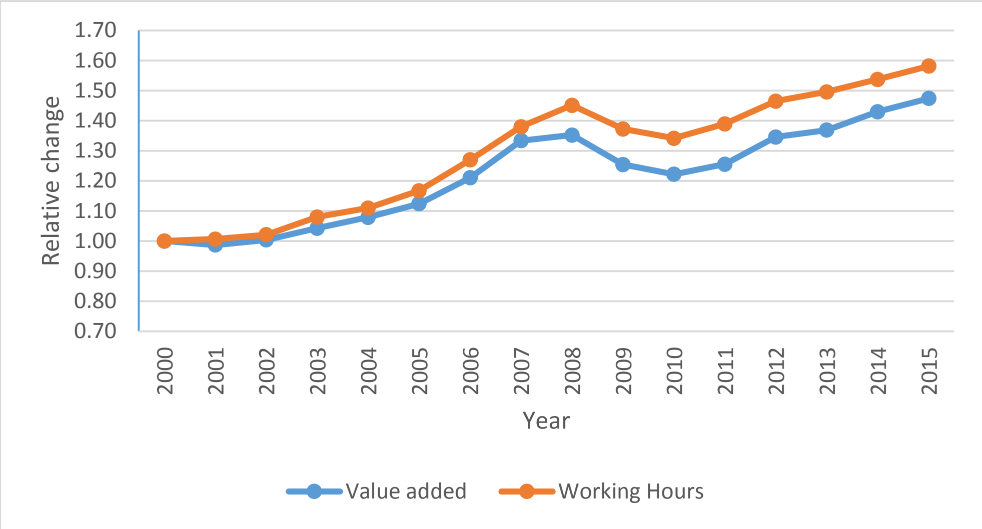

Figure 9: F relative value added and working hours

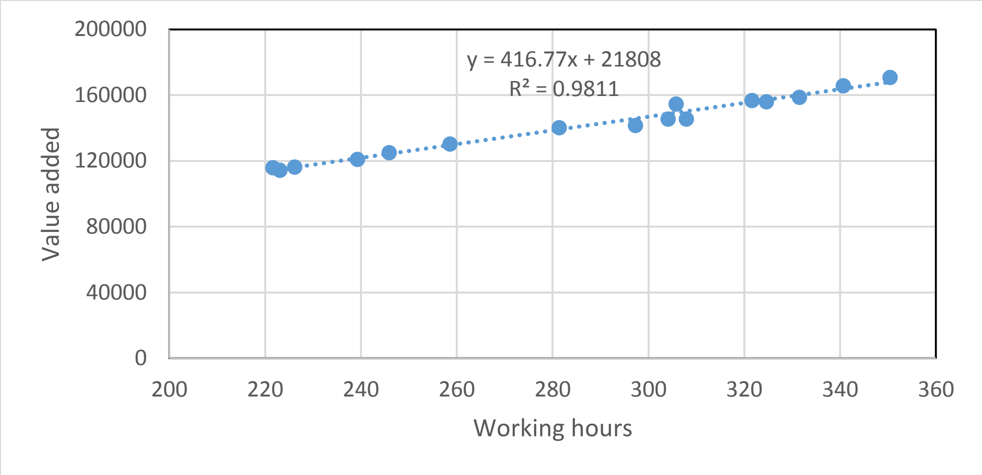

Figure 10: LP trend of Construction and on-site construction

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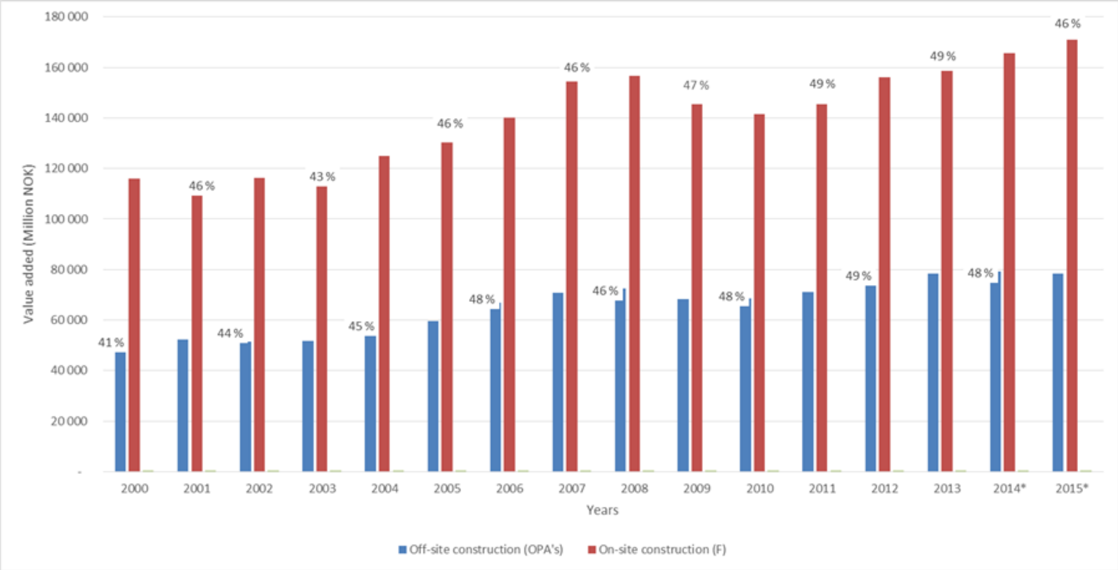

Figure 11: Percentage value added by off-site construction (OPA's) to on-site Construction (F)

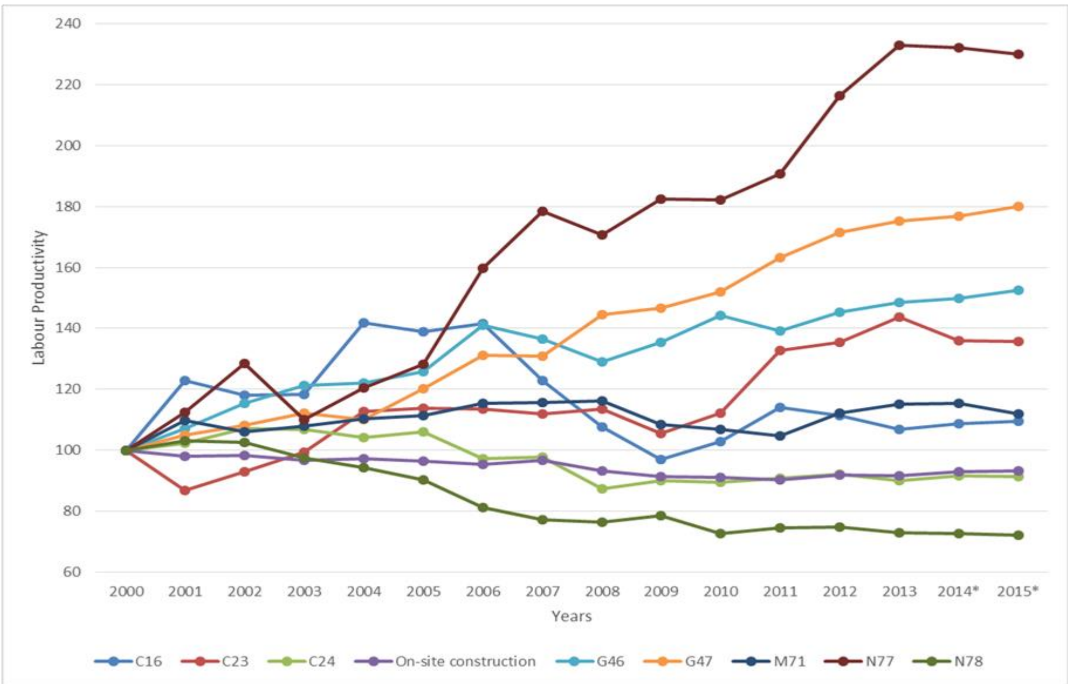

Figure 11: LP trends of on-site construction (F) and off-site construction activities (OPA)

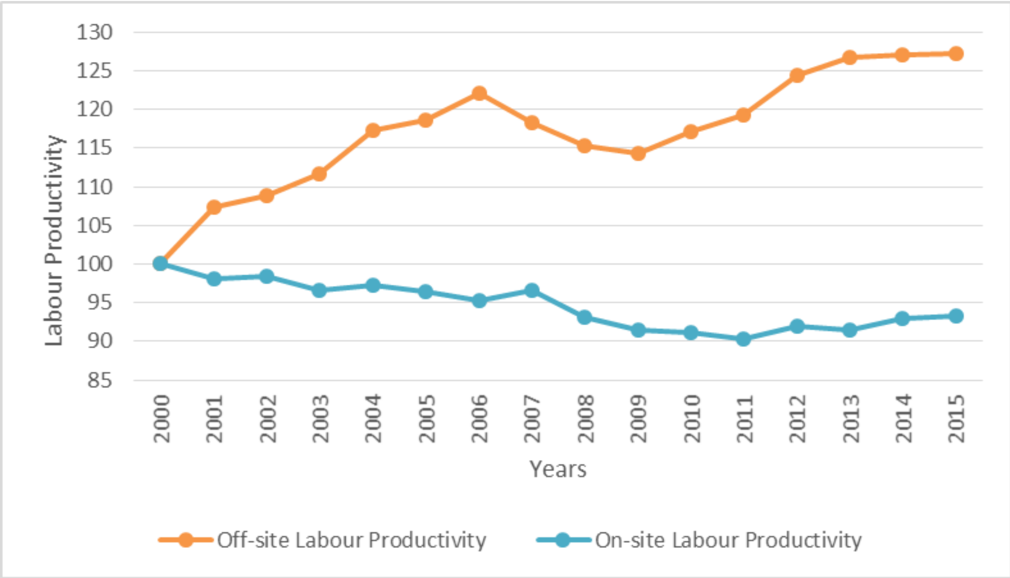

Figure 13: LP trend of On-site construction (F) Vs Off-site (OPA)

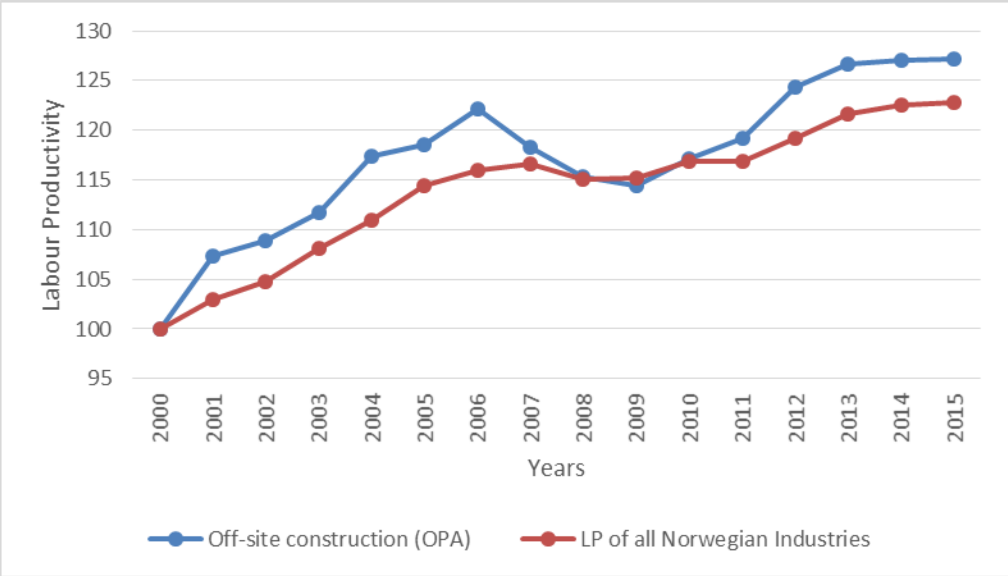

Figure 14: LP trends of off-site construction (OPA) Vs Norwegian industries

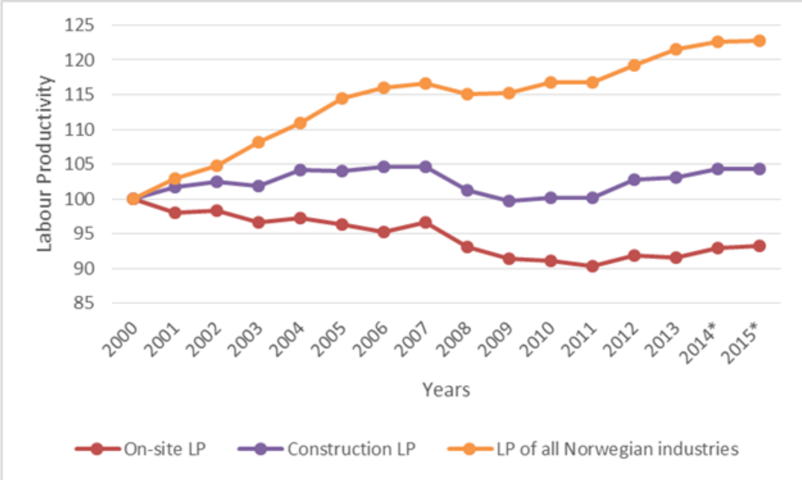

Figure 15: LP of on-site, Construction LP and LP of all Norwegian industries