

# Macroeconomic Labor Productivity and Its Impact on Firm's Profitability

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## **Macroeconomic Labor Productivity and Its Impact on Firm's Profitability**

### **ABSTRACT**

The construction industry is one of the largest sectors in the U.S. economy, yet little is known about the key macroeconomic parameters that affect its industry's structure and performance. The main objectives of this research are 1) to analyze the macroeconomic performance of construction industry as a whole and at fourteen of its sub-sectors in terms of labor productivity, gross margin, and worker's wages; and 2) to develop a quantitative model that predicts a firm's profitability by analyzing various levels of labor productivity. The results of a non-linear regression analysis based on the comprehensive U.S. Economic Census data show that the construction industry's sub-sectors with the highest productivity are the most profitable with regard to the gross margins that they are able to generate. This study and its model will help decision makers better assess macroeconomic performance and conduct trend analysis of the construction industry to serve as a basis for developing strategic roadmap for the future.

**Keywords:** *Labor Productivity, Gross Margin, Construction, Project Management, Regression Analysis*

## 1 INTRODUCTION

Construction industry is an integral part of any nation's economy, whether measured by dollar volume or workforce size. In the United States, the value of construction work put in place was almost \$837 billion, or about 8% of the Gross National Product (GNP) in 2007 (U.S. Census Bureau, 2012). The industry also accounted for the employment of more than 8.1 million people and nearly 1.5 million people in related fields (U.S. Census Bureau, 2011a). However, research on labor productivity and performance of the construction industry and its sub-sectors has been fairly limited, given the substantial size of the industry and its perennial influence on the nation's economy.

Architecture, engineering, and construction industry experts believe that one of the most critical challenges in improving productivity is the lack of reliable labor productivity data (Tuchman, 2003). As a result, overall performance of the construction industry remains mostly unmeasured (Goodrum and Hass, 2002), and concerns have been constantly raised that there are no accurate measures of labor productivity data for the industry and its sub-sectors (Chapman and Bustry, 2008). The inability to acquire reliable labor productivity data has become a major impediment to improving productivity for the construction industry, because the limited number of theoretical studies in the measurement and interpretation of the industry's performance data inhibits a clear vision for performance improvement and industry growth.

This paper addresses the need for such research by analyzing data and drawing conclusions on the difference and changes in productivity, gross margins, and wages among the industry's sub-sectors.

The analysis of this research has shown that some sectors in the construction industry have suffered a loss in performance, while other sectors have made great strides in improving performance. Specifically, for the construction industry as a whole and 14 of its sub-sectors, this paper aims at:

1. Quantifying sizes and economic characteristics, specifically macroeconomic labor productivity, gross margin, and labor wages.

2. Investigating the statistical relationship among the three key parameters by performing a correlation coefficient analysis; and
3. Developing a quantitative model that predicts the level of a firm's profitability as a function of other key parameters by performing a non-linear regression analysis with a best-fitting least squares curve on the plotted scatterplot.

This research will provide insights that decision-makers and planners in each sub-sector in the industry can use to devise effective business strategies by considering the magnitude and trends of key performance parameters. Moreover, research into the macroeconomic characteristics of the construction industry and its sub-sectors provides a clearer focus on the strengths, weaknesses, and needs of the industry to have a roadmap for future growth and performance improvements.

## **2 LITERATURE REVIEW**

Prior to conceiving the research methodology for this study, it was necessary to identify existing relevant research work. Studies related to the measurement of productivity and performance in the construction industry have been fairly limited (BFC, 2006). In terms of labor productivity, previous studies focused on the investigation of labor productivity trends over time at the industry-wide level. Systematic research has not been conducted to estimate such economic characteristics at the sub-sector level, yielding no consensus of labor productivity trends (Allmon et al, 2000; Rojas and Aramvareekul, 2003).

A research study concluded that labor productivity itself would not be the sole source responsible for cost overruns and schedule delays; rather poor planning and improper management should be dealt as one of the main reasons (Chanmeka et al, 2012). The study by Hendrickson and Au (2008) discovered that the level of management in a given construction firm was not a principal contributor to labor productivity increases over time. This finding contradicts a previous analysis that the higher level of management

results in a greater level of labor productivity (Bloom et al, 2007), although construction methods, planning, supervision, and jobsite conditions play an important role in determining the level of productivity (Ghoddousi and Hosseini, 2012). Jarkas (2012) explained how the design and geometry of any construction activity at the job site influence the labor productivity by introducing a few example cases, which may have either positive or negative implications on labor productivity. In another study carried out by Jarkas (2011), the relationship between construction efficiency of any activity and its related impact on labor productivity was examined, arrived at a conclusion that the relationship between construction efficiency and labor productivity may vary within various subsectors at the industry-wide level. Efficiency of equipment used at the construction site is also being cited as one of the important factors favorable affecting labor productivity. Shen et al (2011) conducted a research study that compares construction equipment efficiency of the U.S. and China, indicating that the U.S. is far ahead of China when it comes to construction labor productivity.

The main conclusion of the Allmon et al's (2000) study was that labor productivity had increased substantially over a decade between the 1980s and 1990s, primarily due to depressed real wages and technological advances. Allmon et al's (2000) study tracked labor cost and output productivity trends for tasks representing different trades and differing levels of technological intensity, using the ratio of equipment to labor cost per unit of output within the building construction sector. The benchmark productivity trends for these tasks came from R.S. Means' cost data, while the Consumer Price Index (CPI) was used to reflect the effect of inflation. In the heavy construction sector, soil compaction activity was chosen as the sample for the industry to measure labor productivity (Stiedl, 1998; Franzluebbbers, 2007). The data associated with direct work rates from 72 different projects in Austin, Texas, were used to compare productivity trends based on R.S. Means' cost manuals.

Rojas and Aramvareekul (2003) also investigated labor productivity trends over time for the entire industry. In Rojas study, labor productivity was calculated from 1979 to 1998 simply by applying the following equation: 
$$\frac{GPO_i}{Employees_i * Hours_i}$$

where  $GPO_i$  is gross product originated by industry  $i$ ;  $employees_i$  is average number of employees for industry  $i$ , and  $hours_i$  is average number of hours worked in industry  $i$ .

The values of GPO in the industry were based on data compiled by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce, while the average number of employees and work hour data were compiled by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor. However, these raw data were proved to be unreliable and invalid, leading to the conclusion that labor productivity trends for the time period could not be determined (Rojas and Aramvareekul, 2003). Consequently, their study recommended that the measurement of labor productivity be examined at the sub-sector level rather than at the industry level since the aggregation of data at the overall industry level camouflages productivity trends at the individual sub-sectors (Rojas and Aramvareekul, 2003).

In general, labor wages are determined as a function of the type of work to be performed and the level of worker's expertise. Labor wages among various industries of the nation's economy have shown a different trend. For instance, labor wages in the construction industry may have a similar or dissimilar trend with the automobile industry (Yeaple, 2005). In fact, in the construction industry there has been a noticeable increase in the labor wages over the past 20 years due primarily to innovations and growing awareness of educated workers (Bartel and Sicherman, 1997). With the growth of the labor wages, gross margins for the construction firms have also witnessed a sharp rise (Bartel and Sicherman, 1997).

### **3 DATA COLLECTION PROCESS**

Compiled by the U.S. Census Bureau every five years, the U.S. Economic Census Report includes highly detailed data about most sectors of the U.S. economy on the local, regional, and national levels (U.S. Census Bureau, 2011b). Three latest U.S. Economic Census Reports of 1997, 2002, and 2007 were used for this study on labor productivity, gross margins, and labor wages for the construction industry. The census data for the 14 sub-sectors of the construction industry, as well as the industry as a whole, contain state and regional level information collected for 51 geographic areas (50 states and Washington D.C.). Although geographic diversification may be an important factor in construction labor productivity (Goetz et al, 2012), this study focuses on the sector-level performance. The three census reports are slightly limited, in that they lack certain data for a number of reasons: (1) companies did not want to share proprietary information in the census; (2) companies did not respond in a timely manner to the census request; and (3) companies miscoded their entries in completing the census. Missing values were estimated and interpolated by performing a simple bivariate linear regression analysis to improve the reliability and validity of these data.

Inflation is another important parameter in macroeconomic studies because it is considered as an indicator of overall economic trends (BLS, 2011). Similar to Allmon et al's (2000) study, this study applied the CPI to capture inflation over time from 1993 to 2007. An inflation calculator provided by the BLS was used to adjust the monetary data of the 1997 and 2002 series to match the dollar value of 2007 (BLS, 2011).

### **4 MACROECONOMIC LABOR PRODUCTIVITY**

Due to its large size and labor force component, the construction industry greatly affects national and local economies, and labor productivity is a key macroeconomic parameter to calibrate the performance of the industry. Among many ways to define productivity (Thomas and Raynar, 1997; Freeman, 2008; Li

and Prescott, 2009), it is possible to define productivity in terms of labor, as a relative measure of labor efficiency in dollar value (Bernstein, 2003).

#### 4.1 Quantifying Macroeconomic Labor Productivity

Given the labor-intensive, diverse and fragmented structure of the U.S. construction industry, there are many possible ways to define and estimate labor productivity. Typically, studies of labor productivity tend to focus on trend investigations of total man-hours of employed field labor over time provided by the BLS. BLS data, however, have had some reliability and validity problems due to deficiencies in data collection, processing, and interpretation (Rojas and Aramvareekul, 2003). To address these problems, values of labor productivity presented in this paper are calculated based on the U.S. Economic Census Reports, adjusted by a linear regression technique as mentioned earlier; this may provide the most detailed, acceptable, and credible measurement of macroeconomic labor productivity for the industry. Although this study attempted to incorporate the BLS's hourly output rate data for construction industry labor into the research for this paper, it proved impractical to combine BLS data with the Economic Census data, since they represent heterogeneous sources from different levels and perspectives.

In this study, macroeconomic *labor productivity* is defined as average throughput (output) of value of construction work per construction worker. *Value of construction work* in turn is defined by the U.S. Census Bureau as the sum of all the value (in dollars) of construction work done by general contractors, as well as special, heavy, and special trade contractors, including new construction, additions, alterations, or reconstruction, and maintenance and repair construction work (U.S. Census Bureau, 2012). To calculate the macroeconomic labor productivity of the 14 sub-sectors and the entire construction industry, the following formula was developed and applied:

$$\text{Sub-sectors } LP_i = \frac{\sum_{j=1}^{51} VC_{ij}}{\sum_{j=1}^{51} NCW_{ij}} \quad (1)$$



In the equation above,  $LP_i$  equals the labor productivity of industry sub-sector  $i$  (state  $j$ ), where  $VC_{ij}$  equals the value of construction work in dollars (industry sub-sector  $i$  in state  $j$ ), and  $NCW_{ij}$  equals the number of construction workers of industry  $i$  in state  $j$ .

## 4.2 Assessing Macroeconomic Labor Productivity

Table 1 shows that labor productivity has improved over the study period from 1992 to 2007 when taking into account all sub-sectors and the industry as a whole. In particular, the land sub-sector, followed by the residential and nonresidential sub-sectors, produced the highest level of macroeconomic labor productivity. As the land sub-sector has the second-lowest labor intensity in the industry (see Table 1), a relatively small number of competitive employees are needed to create the high value of construction work within the land sub-sector. This high productivity also results from the land sub-sector's primary role of site acquisition and pre-development market research and analysis, not physical development. Even though the nonresidential and residential sub-sectors typically experience the highest labor intensity (Page and Curtis, 2011), good labor productivity performance in these sub-sectors is attributed to the fact that they create the second highest value of construction work (see Table 1). Based on the North American Industry Classification System (NAICS) codes, the residential building construction sector can be categorized into two main housing construction subgroups: (1) single family and (2) multifamily (U.S. Census Bureau, 2011c). The nonresidential building construction sector is also divided into two building construction subcategories: (1) industrial and (2) commercial and institutional. In addition to high labor productivity performance, the residential sector constitutes 63 percent of the private-sector activity in the United States construction industry (Anderson, 1994). Therefore, it is estimated that overall the high productivity in this sector exercises the highest leveraged effects on the nation's construction industry.

<Insert Table 1 Here>

According to the theory of age, the trend of consumers seeking residential space shifts from the “age of quantity,” whose objective is for builders to produce just enough shelter to meet market demands, to the “age of customization,” whose objective is to increase the extent to which builders’ products are differentiated (Laidler, 1991). Therefore, as the elastic demand for high-quality, affordable residential space increases over time in the inelastic supply structure, the residential sector often experiences periods of many innovations in building and housing construction projects, including additions, alterations, and reconstruction, as well as repairs and remodeling. This rapid adoption of innovative practices contributes to high labor productivity in the residential sector. Even though the construction industry is known to adopt innovation rather slowly (Sabol, 2007), the residential sector in particular quickly adopts innovations such as modularization, panelized housing systems using prefabricated materials, and other engineered products (Koebel et al, 2004; Lutzenhiser et al, 2009).

Housing construction’s strong commitment to innovation as a business survival strategy serves not only to reduce direct costs but also to improve macroeconomic labor productivity in several ways. For example, the use of predrilled studs in wall framing and the use of sealed panels in roof insulation save labor steps and contribute to a higher rate of labor productivity. Rapid population growth is also a contributing factor to improved labor productivity (Bloom and Freeman, 1986; Chansarn, 2010). As the population steadily increases, cities are simultaneously expanding, sometimes at great speed, creating an accelerated demand for more affordable housing in metropolitan areas to be built by existing construction firms.

The high productivity of these sub-sectors contrasts with the painting and wall-covering sub-sector, which has the least macroeconomic labor productivity value, as shown in Table 2. This sub-sector has high labor intensity with relatively little value of construction work: the second smallest value in 1997 and the smallest in both 2002 and 2007, followed by the masonry, drywall, and tile sub-sector. Both of these sub-sectors are typically filled through a subcontractor’s role in construction projects, and rarely create much value beyond the cost of materials and prevailing labor rates.

<Insert Table 2 Here>

## 5 LABOR WAGES

In this study, labor wages were computed using the Equation (2) to examine the validity of the research hypothesis that there is a significant relationship between the level of labor wages and labor productivity. It has been believed that higher payments for labor have contributed to labor's high productivity in generating gross margins. If labor wages are determined by an economic supply-demand curve, a higher demand may result in a wage increase over time. To calculate the macroeconomic labor wages of the 14 sub-sectors and of the entire construction industry, the following formula was developed and applied:

$$WPC_i = \frac{\sum_{j=1}^{51} TW_{ij}}{\sum_{j=1}^{51} NCW_{ij}} \quad (2)$$

where  $WPC_i$  equals the wages of sub-sector  $i$  in state  $j$ ;  $TW_{ij}$  equals the total wages for sub-sector  $i$  in state  $j$ ; and  $NCW_{ij}$  equals the number of construction workers in sub-sector  $i$  in state  $j$ . Table 2 indicates that labor wages in the construction industry have increased over the study period from 1992 to 2007.

## 6 GROSS MARGIN

Most construction firms appear to be strongly committed to improving productivity. Firms in productive sectors are more profitable than those that are not; opportunities for growth are also seen to be higher. The reason for the latter is that productive (profitable) sectors can better absorb the business risks associated with the implementation of innovations or new business strategies for growth (Bernstein, 2003). To identify the most productive – and therefore most profitable – sub-sectors, gross margins were evaluated in connection with the sub-sectors' macroeconomic labor productivity and labor wages.

## 6.1 Quantifying Gross Margin

In this study, *gross margin* is defined as the firm's profit before operating expenses. The estimates of the 14 sub-sectors' gross margins were calculated using industry revenue and general and administrative expense information, including employees' wages, equipment rental costs, capital expenditures, material costs, and subcontractors' fees. To calculate the gross margin per construction worker in each of the 14 sub-sectors, the following formula was developed and applied:

$$GPC_i = \sum_{j=1}^{51} \left( \frac{Revenue_{ij} - G \& A Expenses_{ij}}{NCW_{ij}} \right) \quad (3)$$

where  $GPC_i$  equals the gross margin per construction worker for industry sub-sector  $i$  (state  $j$ );  $Revenue_{ij}$  equals total revenue; and  $G\&A Expenses_{ij}$  equals the general and administrative expenses for sub-sector  $i$  in state  $j$ .  $NCW_{ij}$  equals the number of construction workers.

## 6.2 Assessing Gross Margin

Table 3 shows that the gross margin per construction worker has improved over the past 15 years. In particular, the residential sub-sector, followed by the nonresidential sub-sector, have experienced the highest gross margins since these sub-sectors generate the highest value added with relatively lower general and administrative expenses. *Value added*, as reported in this study, is defined as the value of construction work done by the sub-sector, less costs for subcontract work, materials, components, and fuels (U.S. Census Bureau, 2011b). However, the high gross margin of the residential sub-sector overall cannot be directly translated into a high profitability at the firm level, since relatively more subcontractors are involved in the residential sub-sector. In most cases, firms in the residential sub-sector are involved in small-scale new building and housing construction projects, and therefore realize less profit because of the unique characteristics of such projects. Therefore, the residential sub-sector realizes a relatively small gross margin ratio, as shown in Table 3.

<Insert Table 3 Here>

The gross margin ratio is a critical variable in determining a sub-sector's profitability potential, defined as the percentage of profit margin on revenue, denoted as Equation 3 divided by the total revenue of each sub-sector. The gross margin ratio indicates how the contracting amount awarded to a construction firm for the project contributes to covering all other expenses and yielding a profit. To illustrate, the land sub-sector's gross margin ratio was estimated at over 47 percent on average over the past 15 years, meaning that about 47 percent of revenue was accounted as profit from 1993 to 2007 (see Figure 1). While the construction industry's overall profitability average is around 2 percent for the same period of time, the land sub-sector, the most profitable sector in the construction industry, far exceeds the industry average. This higher level of gross margin could be achieved through increasing sales, reducing general and administrative costs, or a combination of both.

<Insert Figure 1 Here>

## **7 MODELING RELATIONSHIP AMONG KEY PARAMETERS**

One of the major objectives of this study was to examine the relationship among three key performance parameters by testing the validity of the research hypothesis that industry sub-sectors with higher productivity and labor wages are more profitable with regard to the gross margins than sub-sectors that represent low productivity and wages. In this study, a firm's profitability was captured by the quantified gross margins per construction worker, believing that construction workers generating more profits also contributed to adding more profits for the firm. The quantified data of all three key parameters were carefully checked for normality and multicollinearity issues to ensure an unbiased analysis. This study employed a Pearson's correlation coefficient analysis to test the validity of the research hypothesis. An exponential least squares function was chosen as the best-fitting curve on the plotted scatterplot. A nonlinear regression analysis was then performed to further investigate the relationships among

parameters to arrive at the final predictive model that determines the levels of a firm's profitability as a main function of labor productivity.

### **7.1 Impact of Labor Productivity and Wages on Firm's Profitability**

Figure 2 shows a positive relationship between labor productivity and gross margin over the study period, wherein the gross margin values are almost mirror images of labor productivity values. This was confirmed by the Pearson's correlation coefficient analysis. Table 4 indicates that the relationship between labor productivity and gross margin is significant, with the  $p$ -value smaller than the set threshold level of .001. However, there was no significant relationship between wages and other two parameters. Therefore, labor wage was not considered as an independent variable in the following regression analysis. A non-linear regression analysis with an exponential least squares curve was performed to develop a profitability prediction model by analyzing how a firm's profitability was affected by the level of labor productivity. The non-linear exponential function proved to be the best-fitting least squares function, as it showed the highest r-square value compared with all other available functions on a plotted scatterplot. A positive r-squared value of 0.862 shows a very strong fit, suggesting that approximately 86 percent of the variation in the gross margin can be explained by differing levels of labor productivity. This conveys the important fact that higher labor productivity produces higher gross margins at the firm level for the 14 sub-sectors (see Table 5 and Figure 3). Therefore, in order to improve gross margins at the firm or employee level, it is critical to create sustained labor productivity improvements; for those sub-sectors in the construction industry that have low profit margins and difficulty in creating economies of scale largely due to small size, improving labor productivity may become more of a survival strategy, especially in an environment of consolidation among industry fragmentation.

<Insert Figure 2 and Figure 3 Here>

<Insert Table 4 and Table 5 Here>

Table 5 shows that the selected exponential equation of gross margin is adequate ( $F\text{-ratio} = 250.267$ , significant at 0.001 level), generating the following regression equation for determining a firm's level of profitability:

$$\text{GPC} = 26.246e^{0.0027982LPC} \quad (4)$$

## 8 MODEL VALIDATION

The robustness of the proposed prediction model of Equation 4 in predicting a firm's profitability was validated using the Predicted Error Sum of Square (PRESS). When creating a quantitative model, validation of the model is essential to ensuring its accuracy and reliability. A typical method of validation is to test the model with new data or holdout data reserved from the original sample. Meanwhile, it is not unusual for researchers to have difficulties in data acquisition. The PRESS is one of the most widely used and preferred validation alternatives because it clearly indicates the predictability and accuracy of the model (Ott and Longnecker, 2000). PRESS determines the quality of prediction by comparing each prediction to the one of a new subset model without the use of each observation that serves as a holdout sample of size 1. The PRESS statistic of a regression model is computed using the following equation:  $\text{PRESS} = \sum_{i=1}^n (y_i - \hat{y}_i^*)^2$  where  $y_i$  is a prediction of the regression model for the  $i^{\text{th}}$  observation, and  $\hat{y}_i^*$  is a prediction of a new subset model for the  $i^{\text{th}}$  observation, which is fitted with leaving out the  $i^{\text{th}}$  observation.

Computing the PRESS statistic of a regression model starts with repetitively fitting a new subset model with leaving out one observation at a time. The statistic is calculated by summing the squared residuals between the predicted values of the original model and the predicted values of each subset model for each observation. The PRESS statistic is then compared to the Sum of Squared Error (SSE), which is the value generated by the proposed regression model. The SSE measures the level of variation by looking at the

sum of the squared differences between each observation and its model's mean. If the value estimated by the PRESS statistic is close to the value of SSE, it suggests that the proposed model possesses a significant predictability. If the value estimated by the PRESS statistics turns out to be several times larger than the value of SSE, the model has a validation issue. The estimated PRESS statistic of the proposed non-linear exponential model was 3.265, and the estimated SSE value was 2.819. As the exponential model yields a PRESS statistic very close to the computed SSE value, it confirms that the proposed model is robust in predicting a firm's profitability as a function of labor productivity.

## **9 DISCUSSIONS**

Comparison of the 14 sub-sectors with regard to labor productivity and gross margins shows that some sectors have suffered a loss while a few others have made significant progress. Specifically, land, residential, and non-residential sub-sectors had the best performance in computed macroeconomic labor productivity, while the painting and masonry sub-sectors had the worst performance. Across the entire construction industry, residential and non-residential sectors had the highest gross margin and gross margin ratio, due to the fact that they generate the most value added, further supporting their high labor productivity. Also, the study revealed that the value of construction work has increased significantly over time in the industry, especially in the major sub-sectors such as residential, non-residential, highway, and HVAC.

It is also noted that labor wages had increased throughout from the industry and sub-sector perspectives. In an industry where the average level of gross margin ratio is about 25 percent, it was found that the land sub-sector was the most profitable in the construction industry with a 47 percent gross margin ratio. Also, the industry sub-sectors with higher levels of labor productivity had higher levels of profitability, more so on a per firm basis than on a per employee basis, as proved by the results of a correlation and regression



analysis. This result indicating that higher productivity results in higher gross margins was supported by a very strong r-square value with positive correlation between labor productivity and gross margin. Finally, a validation study proved the robustness of the proposed predictive model in projecting a firm's profitability as a function of varied levels of labor productivity.

A number of critical factors must be improved to create practical and sustained labor productivity improvements. This study shows a strong impact of labor productivity on a firm's profitability, but also has revealed that over the past fifteen years some sub-sectors were experiencing a notable growth in labor productivity while some were suffering from tardy productivity growth. It is, however, important to understand the complex, multi-faceted nature of the construction industry, which can explain many of the sharp differences in labor productivity among the 14 sub-sectors.

Beyond their structural differences, a number of practical trends may explain the disparities in gross margin and labor productivity in the 14 sub-sectors. First, the construction industry has suffered from labor shortage. Noticeable changes in labor-force participation had occurred in the construction industry over the study period. It is believed that the construction industry has not been successful to attract labor from other industries in recent years because of poor working environments, insufficient job growth opportunities, depressed wages, and low performance incentives.

Second, the level of project management would be a crucial factor affecting the labor productivity and gross margin. In a practical sense, effective project management can predict and quantify potential problems in a project to better control and reduce bottlenecks and disruptions. A lack of effective decision making is a major hindrance to labor productivity; a low level of management commitment – rather than

the quality of the workforce – has been cited as the major cause of poor labor productivity (Sanvido, 1988; Assaf and Al-Hejji, 2006; Chanmeka et al, 2012).

Third, technological and organizational innovations would produce sustained productivity improvements in most industries, even those with low wages. However, only 0.5 percent of the construction industry's aggregate budget is devoted to research and development of innovation (Lemer, 1996). Lastly, some sub-sectors have invested in more modern plants, equipment, methods, and materials to improve productivity, as capital-intensive innovations have been seen as more economical than reliance on technologies that utilized more increasingly expensive labor; however, such investments are only undertaken once firms believe that trends that require innovation will continue (Turin and Reid, 1975; Loof and Heshmati, 2002; Loss and Timmer, 2005; Shen et al, 2011; Ghoddousi and Hosseini, 2012).

## **10 CONCLUSIONS AND FUTURE RESEARCH**

This paper has examined the macroeconomic performance of the construction industry by focusing on three key parameters that affect the industry's performance from the perspective of industry sub-sectors. This paper also has investigated the magnitude and trends of macroeconomic labor productivity, wages, and gross margin in the industry. Data from the three-time series of U.S. Economic Census Reports covering the past 15 years from 1992 to 2007 were evaluated and organized by the 14 construction sub-sectors. Missing values in the collected data were interpolated by applying a bivariate linear regression technique.

This research concludes that the industry sub-sectors with the strongest productivity are the most profitable with regard to the gross margins that they are able to generate. The paradigm of labor productivity has shifted away from “working harder and longer” toward “working smarter,” whereby

improvements in productivity can offset labor limitations contained within the structure of the U.S. construction industry. Therefore, it is crucial for each sub-sector in the construction industry to invest more time and resources in devising ways to improve sustained and efficient macroeconomic labor productivity to realize greater profitability. The findings of this study should be of value to decision makers and strategic planners who need to make critical strategic decisions on firm's business directions, as this research provides scholars and industry practitioners with the first view they can use to develop business strategies by looking at the trends and percentages of key macroeconomic performance parameters. This study will help them make better-informed business decisions by understanding the strengths, weaknesses, and needs of each sector in the construction industry. The predictive model would help them develop a business strategy for future growth and productivity improvements in more viable ways. The non-linear regression method and PRESS validation technique adopted in this study can be repeated by other researchers knowledgeable about the operational research field.

This study has attempted to develop a prediction model of firm's profitability by investigating the macroeconomic performance of the construction industry at 14 of its sub-sectors. The industry sector-wide study provides a basis for future research analyzing and comparing the State level macroeconomic performance such as looking into the productivity and wage trends of the highway sector between California and Florida. The predictive model developed in this study can be tailored by applying a cluster analysis technique. The current model's capability in predicting the firm's profitability can also be enhanced by considering additional performance parameters.

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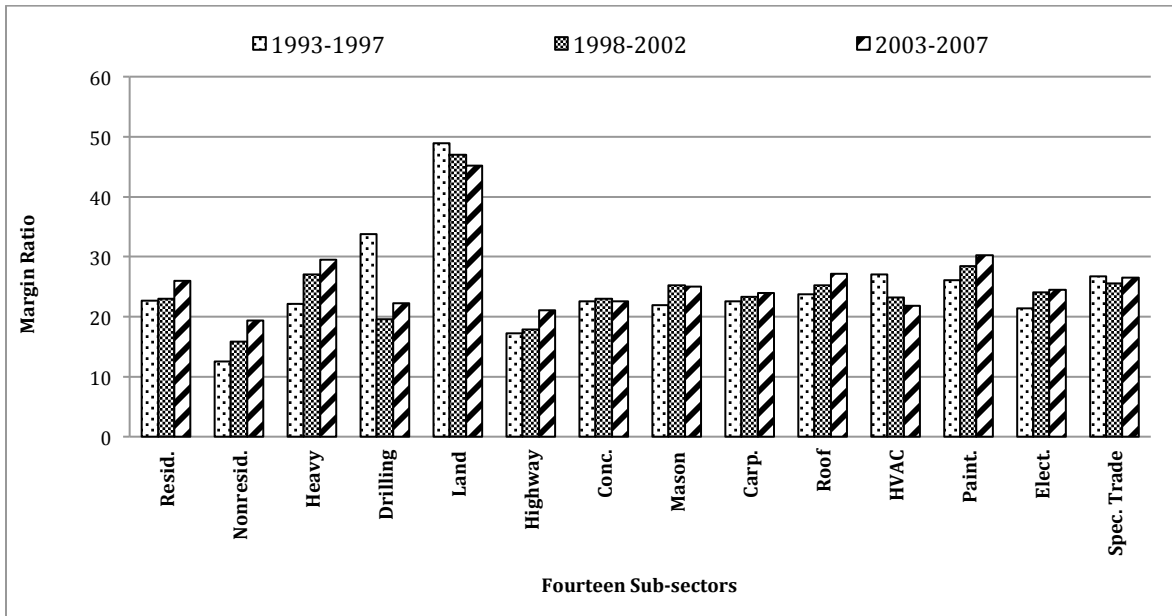
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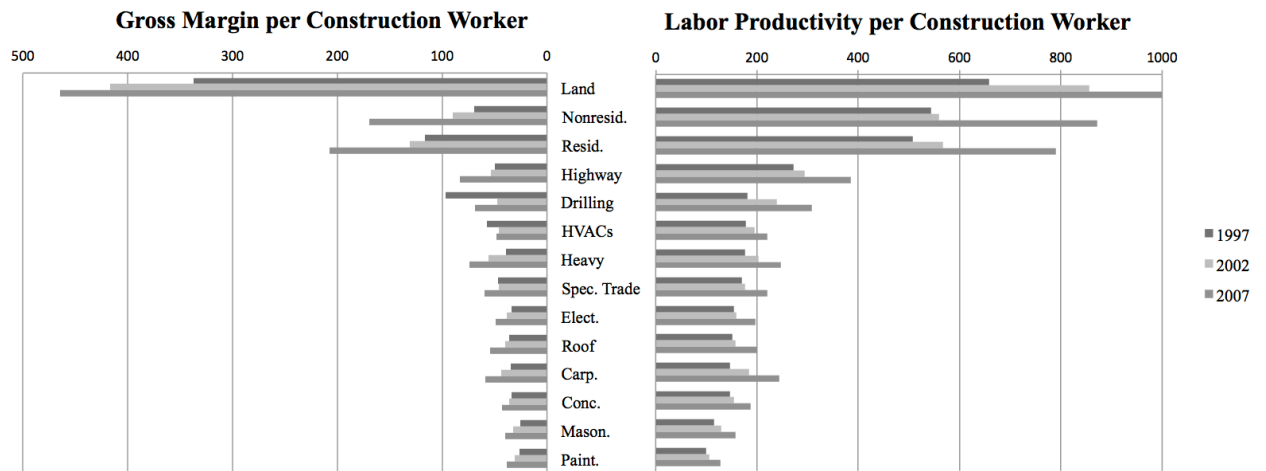
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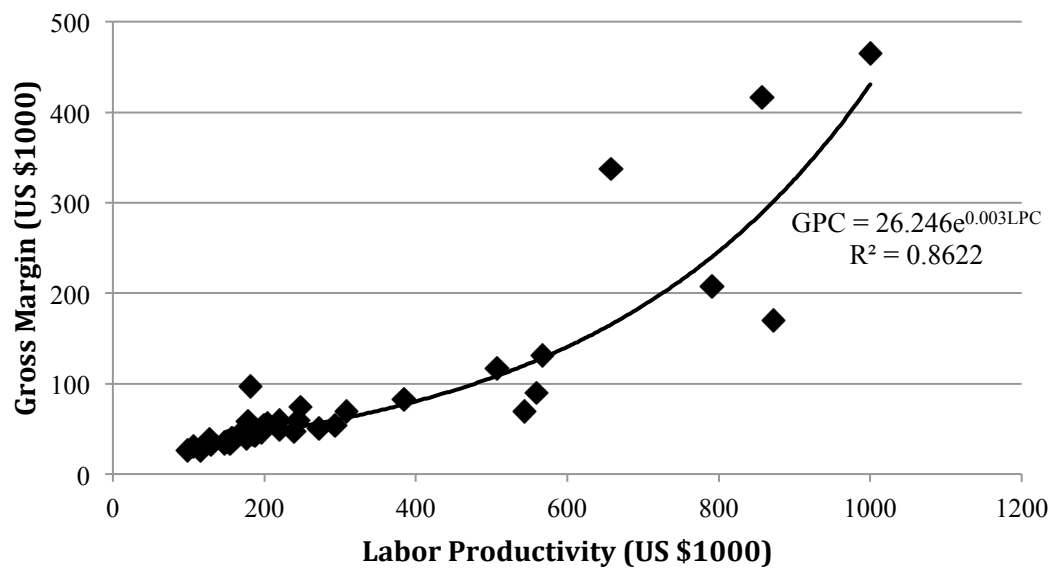




**Figure 1** Magnitude and trends of gross margin ratios over time



**Figure 2** Relationship between productivity and gross margin



**Figure 3** Regression model with a very high r-squared value

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**Table 1** Trends of labor productivity over time from 1992 to 2007 (in 2007 U.S. dollars)

Sub-sectors	Value of Construction Work (US \$billion)			Number of Construction Workers (Unit \$1000)			Labor Productivity per Construction Worker (US \$1000)		
	1997	2002	2007	1997	2002	2007	1997	2002	2007
Resid.	206.54	302.95	355.98	407.34	534.57	450.23	507.06	566.71	790.66
Nonresid.	259.19	298.5	387.92	476.98	533.21	444.85	543.39	559.81	872.03
Heavy	89.93	76.52	81.71	508.43	375.37	330.44	176.88	203.86	247.28
Drilling	2.8	37.43	47.85	15.45	156.69	155.33	181.67	238.92	308.09
Land	17.74	16.05	22.25	26.97	18.73	22.24	657.74	856.71	1000.21
Highway	75.48	93.83	104.25	277.2	319.76	271.01	272.32	293.43	384.68
Conc.	32.62	48.97	62.43	222.11	316.88	332.82	146.87	154.56	187.58
Mason	47.4	65.63	80.14	408.54	508.98	509.04	116.04	128.95	157.44
Carp.	33.43	31.72	41.49	227.17	171.54	169.86	147.18	184.9	244.27
Roof	29.89	31.46	36.08	198.29	200.19	180.75	150.75	157.17	199.65
HVAC	107.11	136.51	159.98	599.93	696.89	727.16	178.55	195.89	220.02
Paint.	15.91	19.44	22.12	160.74	182.45	172.27	99.04	106.56	127.68
Elect.	77.68	95.27	126.22	502.27	597.2	640.95	154.68	159.53	196.93
Spec. Trade	67.2	124.75	187.48	396.1	705.23	851.77	169.67	176.9	220.11
Average	75.92	98.5	122.56	316.25	379.83	375.62	250.13	284.57	368.33

**Table 2** Labor wages trends from 1993 to 2007 (in 2007 U.S. dollars)

Industry Sector (1)	1993-1997 Labor Wages per Construction Worker (US \$1000)	1998-2002 Labor Wages per Construction Worker (US \$1000)	2003-2007 Labor Wages per Construction Worker (US \$1000)
Resid.	21.41	31.18	37.77
Nonresid.	30.00	41.49	46.46
Heavy	26.82	44.01	52.61
Drilling	25.99	38.95	42.88
Land	9.15	38.09	48.86
Highway	32.44	40.66	48.08
Conc.	23.85	34.15	37.82
Mason	24.74	33.17	34.48
Carp.	22.55	31.37	34.73
Roof	22.04	28.20	30.24
HVAC	30.47	42.47	43.66
Paint.	21.34	28.12	30.33
Elect.	31.01	43.11	44.23
Spec. Trade	28.02	35.94	39.04
Average	24.99	36.49	40.80

**Table 3** Trends of gross margin over time from 1992 to 2007 (in 2007 U.S. dollars)

Industry Sector	1993-1997 G.M. per Construction Worker (GPC) (US \$1000)	1998-2002 G.M. per Construction Worker (GPC) (US \$1000)	2003-2007 G.M. per Construction Worker (GPC) (US \$1000)
Resid.	116.32	130.94	207.3
Nonresid.	69.15	89.64	169.46
Heavy	39.18	56.13	74.09
Drilling	96.7	47.15	69.07
Land	337.07	416.93	464.59
Highway	49.84	53.77	82.91
Conc.	33.58	35.72	42.56
Mason	25.69	32.66	39.55
Carp.	34.54	43.74	59.04
Roof	35.99	39.8	54.56
HVAC	57.64	45.77	48.48
Paint.	26.03	30.51	38.74
Elect.	33.47	38.63	48.7
Spec. Trade	46.81	46.01	59.31
Average	71.57	79.1	104.17

**Table 4** Results of Pearson's correlation coefficient analysis

	Labor productivity per construction worker (LPC)	Wage per construction worker (WPC)	Gross margin per construction worker (GPC)
LPC	1.0000	0.2351	0.8695*
WPC	0.2351	1.0000	0.0996
GPC	0.8695*	0.0996	1.0000

- \*The *p-value* is 0.0000, indicating a significant relationship between LPC and GPC.
- WPC does not produce any significant relationship on both LPC and GPC (*p-value* > 0.05).
- The R-squared value of 0.8695 indicates a very strong fit between LPC and GPC.



**Table 5** Results of non-linear regression analysis

Model	Coefficient	Std. Error	Beta	t-value	p-value
Constant	26.246*	0.067		48.641*	0.000
LPC	0.003	0.000	0.929	15.820	0.000
R <sup>2</sup> : 0.862 Sum of Squares for Error (SSE): 2.818 F-ratio: 250.267 ( <i>p</i> =0.000)					
* these values show the results after log transformation					