Different Interaction Mechanisms of Market Structure in the Construction Industry TFP from the Spatial Perspective: A Case Study in China

Bingsheng Liu*, Yuan Chen**, Ran Wang***, Yinghua Shen****, and Qiping Shen*****

Abstract

Total Factor Productivity (TFP) is a measure of long-term economic growth and a comprehensive industry-level productivity measure. China's construction industry exhibits a ladder-like distribution among the central, western and eastern regions and has low productivity. Using methods consisting of the DEA-Malmquist index, measurement for the market structure, and panel data model in accordance with the Structure-Conduct-Performance (SCP) paradigm, this study systematically analyzed the different interaction mechanisms of scale structure, ownership structure, industrial structure, and specialization structure of China's construction industry among the western, central and eastern regions over the past six years. It finds that the traditional SCP paradigm of the industrial economy is also applicable to the construction industry. The enterprise scale has a positive impact on the construction industry TFP of the entire country and the western region, while the proportion of state-owned enterprises has a negative influence on the construction industry TFP of the entire country and particularly the western area. Meanwhile, industrial structure has a positive effect on the construction industry TFP of the eastern area and a negative effect on that of the central area. Additionally, the proportion of general contractors on construction enterprises has a positive impact on the regional construction industry TFP. The research method presented in this study can be applied to other countries as well as to other industries, analyzing the interaction mechanisms of market structure in productivity from the spatial perspective. Therefore this study provides a systematic research methodology for the measurement of regional industry productivity and the identification of impact factors.

Keywords: total factor productivity, DEA-Malmquist index, market structure, interaction mechanism

1. Introduction

Construction productivity is a comparison between input and output (Allmon et al., 2000). However, the productivity of the construction industry has attracted more attention from scholars since David Pearce published a report titled The Social and Economic Value of Construction in 2003. For example, China's construction industry has become the fourth-pillar industry in the 21st century, after industry, agriculture and commerce. In 2012, the total output value of the construction industry was 2,152.6 billion dollars, a 16.2% increase over 2010; construction companies earned 76.7 billion dollars, an increase of 15.6% (National Bureau of Statistics of China, 2013). The prosperity of the construction industry stimulates the development of closely related industries, such as mechanical manufacturing, metalwork, building materials and non-metallic minerals, which plays an irreplaceable role in China's regional economic development. However, the productivity of China's construction industry is generally low, and exhibits a ladder-like distribution among the central, western and eastern regions (Wang et al., 2013). Therefore, to optimize the market structure of the construction industry toward improving competition, it is of practical importance to analyze the reason for low productivity in China's construction industry.

From the perspective of space and industrial market structure, this paper draws on studies of construction industry productivity (Liu et al., 2013a; Wang et al., 2013) and adopts three analysis tools (DEA–Malmquist indicator, measurement for the market structure, and panel data model) to systematically analyze the different interaction mechanisms of scale structure, ownership structure, industrial structure, and specialization structure of China's construction industry among different regions over the past six years. The research method proposed above can be applied to a variety of industries, and it provides a systematic research methodology for the measurement of regional industry productivity and the identification of impact factors. Moreover, although this paper is a case study in China, still it provides certain reference for some developing countries in which construction industry is a major pillar industry. The goal is to effectively improve construction industry productivity by analyzing its market structure. Thus, the main objectives of the study are to:

1. Explore the applicability of the SCP theory for the construction industry
2. Reveal the differences in the internal interaction mechanisms of market structure on construction industry performance
3. Propose the future direction of construction industry in each region of China.

The structure of the reminder of this paper is as follows. We introduce the methods of this paper, including the DEAMalmquist index, measurement approaches of construction industry market structure and panel data model. Then we present that the empirical research was conducted using 31 provinces in China from 2007 to 2012, and the aforementioned methods were used to analyze the TFP and market structure of China's construction industry as well as its spatial analysis of different market structure interaction mechanisms on the construction industry TFP. The final section summarizes the conclusions and proposes some suggestions drawn from the results of this research.

2. Literature Review

In the construction industry field, there are a large number of scholars conducting studies about productivity, for example, Wolgemuth et al. (1982), Sonmez and Rowings (1998), Allmon et al. (2000), Park et al. (2005), Hanna et al. (2005), Xue et al. (2008), Shen et al. (2010), El-Gohary and Aziz (2013), Hwang et al. (2014). However, the definition of productivity isn't still uniformed (Hwang, 2013). Two productivity concepts, Labor Productivity (LP) and Multi-Factor Productivity (MFP), were initially adopted by researchers. However, LP and MFP are misleading concepts when applied to the measurement of construction productivity performance at the industry level because the role of materials in productivity improvement is ignored (Chau and Walker, 1988; Zhi et al., 2003). Therefore, neither of them can reflect the whole process of production and the impact of technology improvement, factor substitution and other factors on productivity (GAO, 2003). In contrast, Total Factor Productivity (TFP) has been recognized as a more comprehensive indicator than LP and MFP for evaluating efficiency in resource usage (Lowe, 1987) and it includes all factor inputs which work together to produce one common output (Wolff, 1981; Gollop 1985; Zhi et al., 2003). The original concept of TFP was proposed by Stigler (1956). TFP is a significant factor used to measure the production unit's development potential and competitiveness; in this way, TFP has been a research focus in economics for a long time (Chau and Walker, 1998). Recently, more scholars have begun to apply TFP to the study of the construction industry, where the research has mainly focused on the measurement of productivity with Data Envelopment Analysis (DEA) or Stochastic Frontier Analysis (SFA) models (Liu et al., 2013a). Wang et al. (2013) reviewed and compared the literature of the TFP measurement in the construction industry and proposed the DEA-Malmquist index as an ideal method to address the insufficient data of the construction industry. Therefore, we will also adopt this method to perform research on the interaction mechanisms of the construction industry's productivity.

There has not been much research on the factors influencing construction industry-level TFP growth (Zhi et al., 2003), though the total number of productivity influence factors in the construction industry is enormous. For example, Kane (1980) and Herbsman (1977) divided them into technological factors and administrative factors. While technological factors included those related mostly to the project design, administrative factors were related to the management and construction of the project. On the basis of macro-economic theory and new economic growth theory, Zhi et al. (2003) combined the features of Singapore's construction industry with a literature review and listed seven factors affecting its construction industry TFP, including technology process, quality of labor, quality of materials, economic level, government regulations, cyclical factors and construction accidents. Denison (1972) set out five ground rules, suggested three criteria that helped guide classification development, and examined some aspects of classification. He found that economy of scale, resource allocation and advances in knowledge had a positive effect on construction industry productivity. Liu et al. (2013a) applied variance analysis to identifying the key factors influencing the productivity of China's construction industry and found that TFP improvement was mainly attributed to technological progress, while the improvement of scale efficiency was only a short-term behavior. Moreover, they found that improving pure technical efficiency would be the key challenge of the construction industry in China. Overall, the construction industry TFP has been studied mainly from a micro perspective, such as at the project or company level. Compared with the industrial organization perspective, this micro perspective is neither comprehensive nor systematic. Moreover, the influencing factors used to evaluate the construction industry TFP are too fragmented. There has been limited research into the interaction mechanisms of construction industry productivity from the perspective of space and market structure.

SCP (structure-conduct-performance) is a classic analysis framework of industrial organization theory with a fundamental theory that market structure determines an enterprise's behaviors and an enterprise's behaviors determine final market performance (Reid, 1987). At present, empirical researches on industrial organization mainly focus on the SCP framework. The interrelationship between market structure and market performance becomes a hot subject for academic study. However, this type of study of China's construction industry is still in a preliminary stage. For instance, Stumpf (2000), Ofori (1996), and Chiang et al. (2001) studied the developing tracks of construction industry structure in Singapore, the United Kingdom and Hong Kong and concluded that the industrial market structure, to some extent, influenced the development of construction industry competitiveness. Zeng et al. (2005) believed that the industrial structure of construction had been severely distorted in China, resulting in low profitability, due to the deep-imprint of the traditional planned economy. Liu et al. (2013b) applied the Panzar-Rosse model to an analysis of the market structure and degree of competition in China's construction industry in order to optimize the industry's market structure and improve competition in the industry. According to the fundamental theory of the SCP framework (Reid, 1987), the construction industry's low productivity mainly results from an unreasonable market competition structure. However, the unique production mode of the construction industry, such as immobility of construction products, production liquidity and multi-level contracting, as well as the regionality and territoriality of the construction market, differentiates the construction industry from the general manufacturing industry. Thus, industrial organization theory focusing on the manufacturing industry cannot be applied to the construction industry fully (Fan, 2010). The internal mechanisms between the market structure and productivity of the construction industry will be a key concern for future studies. Based on this background, China is used as a case study in this research to analyze the interaction mechanisms of market structure in the construction industry TFP in each region and the whole country. The research method that was adopted to achieve the objectives of the study is described in the following section.

3. Method

This study includes three main parts: DEA-Malmquist index, measurement for market structure of the construction industry and panel data model. First, we adopt the DEA–Malmquist index to measure the construction industry TFP. The biggest advantage of the DEA-Malmquist index, as well as the reason why we chose it, is that it does not require input or output prices, which are necessary for other productivity indices (Grifell-Tatjé and Lovell, 1996). Therefore, this method is ideal for situations with insufficient data. Moreover, it can measure the dynamics of TFP. Of course, it is imperfect. Its biggest drawback is the assumption that random errors have no impact on the efficiency rates, leading to the result that the efficiency measured includes the effect of random errors. Second, industrial market structure refers to the centralized or decentralized level of enterprises in an industry and to competition, labor division or cooperation relationships among large-, medium- and micro-sized enterprises. Thus, we apply the measurement for market structure to grasping the current situation of the market structure in the construction industry. Finally, the panel data model is used to analyze the interaction mechanisms of market structure in the construction industry TFP. We choose this method because the panel data model combines the information from time series and section data. We can select multi-sections in a time series and choose sample data on different sections. Thus, the panel data model, one of the most important methods of econometrics, has a good application value. In terms of the link between the three methods, the first two methods are conducted to prepare for the third method, that is, the results of the first two methods are the inputs of the third method, and the third method is conducted to uncover the relationship between TFP and market structure, which can be obtained through the first two methods respectively. The second method will prove the applicability of the SCP theory for the construction industry, which is the first object. And the result of the third method will reveal the differences in the internal interaction mechanisms of market structure on construction industry performance, which is the second object. By analyzing and discussing the result of the third method, we will accomplish the third object that we will propose the future direction of construction industry in each region of China. The principles of each analysis tool used are described in the following sections.

3.1 DEA-Malmquist Index

TFP measurement mainly consists of two approaches: the parameter estimation method with the Solow residual as a representative and the Malmquist index approach based on the DEA model. Before applying the parameter estimation method, some specific forms of production functions should be established. Then, the estimation of TFP is realized in accordance with the coefficient of fitting regression to be determined. However, due to the uncertainty of production function, selecting different models leads to different results, which hinders the popularization of the theory. In contrast, DEA is a non-stochastic, non-parametric, Linear Programming (LP) method that measures the relative efficiency of similar Decision Making Units (DMUs) with common inputs and outputs. Given a set of DMUs with multiple inputs and outputs, DEA determines a best-practice or efficient frontier without a priori information on tradeoffs among inputs and outputs

(Chen and Iqbal, 2004). Moreover, DEA doesn't need to set specific forms of production functions, which can avoid deviation of estimation results caused by different settings of production functions.

Färe et al. (1992, 1994a, 1994b) developed a DEA-based Malmquist productivity index that measured the productivity change over time. The Malmquist productivity index was developed by Malmquist (1953) and used as a productivity index by Caves et al. (1984). Then this method is used in the various studies: in Kumar (2006) for industry in India for 1982-2001; in Mahmood and Afza (2008) to compare East Asia countries by productivity; in Patricio et al. (2012) to estimate efficiency for a group of Chilean universities; in Keskin and Degirmen (2013) to measure the total factor productivity and the changes in components of the total factor productivity generated by the banks in Turkish Banking Sector.

According to Färe et al. (1992), its fundamental principle is as follows:

Suppose in time period $t(t = 1, 2,..., T)$, $x^t_{k,n}$ and $y^t_{k,m}$ indicate n inputs and m outputs in DMU $k(k = 1, 2,..., K)$, respectively. On the condition of a constant return to scale, production frontier inputs can be expressed as $L^t(y^t|C,S) = \{x^t_{k,n} \geq \sum_{k=1}^{K} z^t_k x^t_{k,n},\ y^t_{k,m} \leq \sum_{k=1}^{K} z^t_k y^t_{k,m}\}$ where $z^t_k \geq 0$ indicates the weight of the DMU k in time period t. Thus, on the condition of (C, S), the input-orientated technical efficiency function can be defined as:

$$F^t(y^t, x^t|C, S) = \min \lambda^k$$

$$s.t \begin{cases} y^t_{k,m} \leq \sum_{k=1}^{K} z^t_k y^t_{k,m}, & m = 1,..., M \\ x^t_{k,n} \geq \sum_{k=1}^{K} \lambda^k x^t_{k,n}, & n = 1,..., N \\ t \end{cases} \quad (1)$$

$z_k \geq 0, k = 1,..., K$

To obtain the Malmquist productivity index (TEPCH) in time period t(t = 1, 2,..., T), the distance function $D^t_i(x^t, y^t)$ was introduced by Färe et al. (1994b), which is the reciprocal of technical efficiency.

$$D^t_i(y^t, x^t | C,S) = \frac{1}{F^t_i(y^t, x^t | C,S)} \quad (2)$$

According to Caves et al. (1984), the TFP index can be expressed by the Malmquist Index as follows:

$$M^t_o = \frac{D^t_o(x^t_o, y^t_o)}{D^t_o(x^{t+1}_o, y^{t+1}_o)} \quad (3)$$

That index measures the technical efficiency from time period t to t + 1 under the technical condition in time period t. Similarly, we can define the technical conditions of time period t + 1 Malmquist index and measure the technical efficiency from time period t to t + 1.

$$M^{t+1}_o = \frac{D^{t+1}_o(x^t_o, y^t_o)}{D^{t+1}_o(x^{t+1}_o, y^{t+1}_o)} \quad (4)$$

3.2 Measurement for Market Structure of the Construction Industry

Industrial market structure refers to the centralized or decentralized level of enterprises in the same industry and to competition, labor division or cooperation relationships among large-, medium- and micro-sized enterprises. Market structure, including the number and scale of enterprises, the barriers for entering and exiting, product differentiation etc., is an important foundation for the study of industrial organization. In general, the features of scale structure are regarded as the main research objects of industrial organization theory. In the construction industry, scale structure, industrial structure and specialization structure are all important factors influencing market structure (Fan, 2010). In contrast with the construction industry in other countries, there were two categories for China's construction enterprises (state-owned enterprises and collective enterprises) before the reform and openingup policy. Over a thirty-year period, China's construction industry has formed multi-economic modes such as state-owned enterprises, collective enterprises, private enterprises and joint-stock enterprises. Therefore, ownership structure is also an essential factor of China's construction industry market structure. Thus, the four aspects listed above are widely used when measuring the market structure of China's construction industry.

3.2.1 Measurement for Scale Structure of the Construction Market (SSCM)

As the core concept of industrial organization theory, market concentration is widely recognized as the principle indicator that reflects the scale structure of enterprises. Market concentration indicators can be separated into two types: absolute concentration and relative concentration. Absolute concentration is typically used to represent the leading enterprises market shares of the entire market, including production, sales and assets (Chiang et al., 2001), while relative concentration reflects the distribution of all enterprises in a particular market and is usually represented by the Lorenz curve (Lorenz, 1906) and the Gini coefficient (Zeng et al., 2005). The study focuses on measuring scale structure of China's regional construction industry. However, in fact, some statistics were not collected about factors such as production, sales or assets. Thus, average scale of enterprises is applied to reflect scale structure of the regional construction market. According to Fan (2010),

$$SSCM = \frac{\text{total output of the construction industry}}{\text{total number of construction enterprises}} \quad (5)$$

3.2.2 Measurement for Ownership Structure of the Construction Market (OSCM)

State-owned economy has played the dominant role of China's construction industry for a long time. In 1993, the implementation of Operating Mechanism Means of the Construction Installation Enterprises With ownership structure, which marked the reform of the property rights of China's construction industry, was carried out in a comprehensive manner. Currently, enterprises with multi-economic ownerships are commonplace in China's construction industry. Large-sized state-owned enterprises not only enjoy absolute advantages in production scale and technological capability but also form a certain degree of monopoly, which hinders fair competition. In contrast, the increasing number of non-state-owned construction enterprises will be a driving force for the establishment of a more fully competitive market, which is an objective requirement of promoting the long-term sustainable development of the construction industry. The proportion of state-owned enterprises is used to reflect ownership structure of the regional construction market. According to Fan
(2010),

$$OSCM = \frac{\text{total output of state-owned construction enterises}}{\text{total out of the regional construction industry}} \quad (6)$$

3.2.3 Measurement for Industrial Structure of the Construction Market (ISCM)

In accordance with industrial classification standard of national economy, the construction industry consists of four main components: the building and civil engineering, construction installation, construction decoration and other construction industries, which form the industrial structure of the construction industry. Building and civil engineering is a major market of the construction industry. Thus, the ratio of total output of building and civil engineering to that of the construction industry reflects the industrial structure of the construction market. According to Fan (2010),

$$ISCM = \frac{\text{total output of building and civil engineering}}{\text{total output of the construction industry}} \quad (7)$$

3.2.4 Measurement for Specialization Structure of the Construction Market (SSOCM)

At present, construction enterprises in China can be divided into general contractors, professional contractors and labor subcontractors. The three types of enterprises with different specialization function form the organizational structure of specialization division of construction enterprises. Since the implementation of the new qualification management approaches in 2001, general contractors and professional subcontractors have become body portion of China's construction industry. Thus, the ratio of number of general contracting enterprises to that of professional contracting enterprises is introduced to demonstrate the specialization structure of the construction market. According to Fan (2010),

$$SSOCM = \frac{\text{total number of general contracting enterprises}}{\text{that of professional contracting enterprises}} \quad (8)$$

3.3 Panel Data Model

Panel data model is applied in this study to further analyze the interaction mechanisms of market structure in the construction industry TFP. The theoretical hypothesis and model selection procedure are described in the following sections.

3.3.1 Theoretical Hypothesis

According to the measurement for market structure of the construction industry, we assume that the construction industry TFP is mainly affected by SSCM, OSCM, ISCM and SSOCM. Thus, if TFP and its influencing factors are regarded as input variables and output variables, respectively, we establish a knowledge output function such as the C-D production function and give theoretical hypothesis as follows:

$$TTP_{it} = f(SSCM_{it}^{\beta_1}, OSCM_{it}^{\beta_2}, ISCM_{it}^{\beta_3}, SSOCM_{it}^{\beta_4}) = SSCM_{it}^{\beta_1} \times OSCM_{it}^{\beta_2} \times ISCM_{it}^{\beta_3} \times SSOCM_{it}^{\beta_4} \quad (9)$$

Take the natural logarithm of both sides of the equation. Then, it can be written as follows:

$$\ln TFP_{it} = \beta_1 \ln SSCM_{it} + \beta_2 \ln OSCM_{it} + \beta_3 \ln ISCM_{it} + \beta_4 \ln SSOCM_{it} \quad (10)$$

Taking into consideration individual effect and time effect as well as other random influential factors, the final theoretical model is set as:

$$\ln TFP_{it} = \beta_1 \ln SSCM_{it} + \beta_2 \ln OSCM_{it} + \beta_3 \ln ISCM_{it} + \beta_4 \ln SSOCM_{it} + \alpha_i + \lambda_t + \varepsilon_{it} \quad (11)$$

where, $\beta_1 \sim \beta_4$ are TFP elasticity value of all the indicators, α_i and λ_t are individual effects and time effects, respectively. $\varepsilon_{it} \sim 0, (\Omega)$ is random error.

3.3.2 Model Selection Procedure

Before making our regression analysis, we should take into account the factors influencing the results and discuss how to address them.

First, both individual and time directions of panel data have fixed effects, random effects and mixed effects. Moreover, specific effects of the two directions can be confirmed with the redundant fixed effect likelihood test (i.e., LR test) and the Hausman test. The mixed regression model serves as the null hypothesis of LR test and the fixed effect model as alternative hypothesis. In contrast, the random effect model is used as null hypothesis of the Hausman test with the fixed effect model as alternative hypothesis. As in the default basic model, individual direction is set as random effect and time direction as fixed effect. If a null hypothesis is significantly rejected by the Hausman test, the individual direction should be the fixed effect model; if LR test is significant, then the fixed effect model should be used for the time direction, otherwise, the mixed effect model will be used.

Second, modern econometric theory holds that regression analysis with unstable variables may lead to spurious regression, resulting in a failure to estimate results, while results of panel unit-root test are better than that of unit-root test of a single time series. Therefore, taking the regression residuals as subjects, the study applies LLC test (Levin et al., 2002) and Fisher-PP test (Maddala and Wu, 1999) to conduct the panel unit-root test. The LLC test can be used in the condition of common unit roots, while Fisher-PP test is available for that with a single unit root. When the null hypothesis

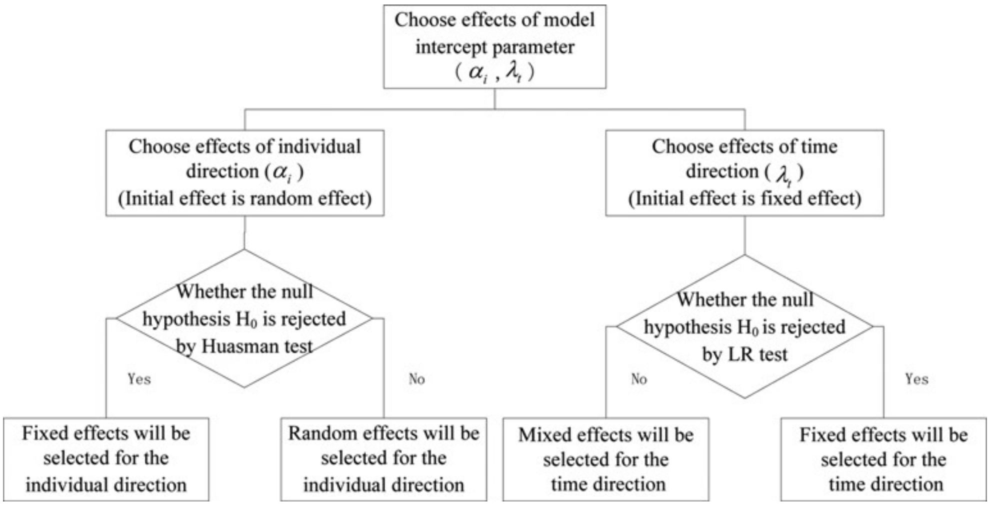

Fig. 1. Model Selection Procedure

is rejected in a given significant level, the regression residual is steady without spurious regression (Xia, 2010). Our model selection procedure is shown in Fig. 1.

4. Influence of Market Structure on China's Construction Industry TFP

4.1 Measurement for the Construction Industry TFP

This research uses China as a case study and takes its thirtyone provinces as the observations (see Fig. 2). Considering the differences in economic strength with respect to geographic location, the provinces are divided into three major regions: eastern, central and western. The eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; the central region includes Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan; and the western region includes Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, and Inner Mongolia.

According to the theory of DEA-Malmquist Index, to calculate the construction industry TFP, input and output indicators of the construction industry should be defined in advance. Liu et al. (2013a) used the added value method to select the gross output value of the construction industry and business investment as two input indicators and to choose total pre-tax profits of construction enterprises and profits of projects settlement accounts as two output indicators. The gross output value of the construction industry refers to the total construction products and services, expressed in monetary terms, produced or rendered by construction and installation enterprises during a given period of time, which is a concentrated expression of the construction industry's output. Business investment of the construction industry refers to the value added of construction industry with profits of projects settlement accounts deducted. The latter basically covers the whole inputs during the reproduction of construction enterprises. The value added of construction refers to the final result of the production and operation activities of the construction industry enterprises in monetary terms during the reference period.

Fig. 2. Map of Chinese Provinces

Total pre-tax profits of construction enterprises is an indicator of the total profits and tax, which reflects the total gained profits and the enterprises' social responsibility in a certain period. Profits of projects settlement accounts are profits after projects were completed. Based on this, Liu et al. (2013a) applied DEAMalmquist Index to calculating China's construction industry TFP, regarded all the provinces in China as thirty-one regions, and then analyzed the factors influencing TFP with variance analysis from the perspective of external environment. To delve more deeply into the interaction mechanisms of market structure in the construction industry TFP from multi-angles, this paper draws on research achievement of Liu et al. (2013a), and calculates China's regional construction industry TFP from 2007 to 2012 (See Table 1). Then, from the perspective of space and industrial market structure, we divide all the provinces of China into three regions and combine features of the regional construction industry to analyze the factors influencing construction industry TFP and its mechanisms.

4.2 Measurement for Market Structure of the Construction Industry

One of the major difficulties in studying the interaction mechanisms of the construction industry TFP has been the lack of data from the perspective of industrial organization (Chau, 1993). For the measurement of the market structure of the construction industry, we took advantage of the Chinese construction industry data from the China Statistical Yearbook (2008-2013) (National Bureau of Statistics of China, 20082013), which is authoritative in China. The period of analysis is designated from 2007 to 2012, owing to data availability. We then calculated all the indicators for market structure of China's regional construction industry from 2007 to 2012 (See Table 1).

Based on the data in Table 1, the averages of TFP, SSCM, OSCM, ISCM and SSOCM of each region during the six years were calculated (see Fig. 3).

Looking at the figure above, it can be discerned that, at present,

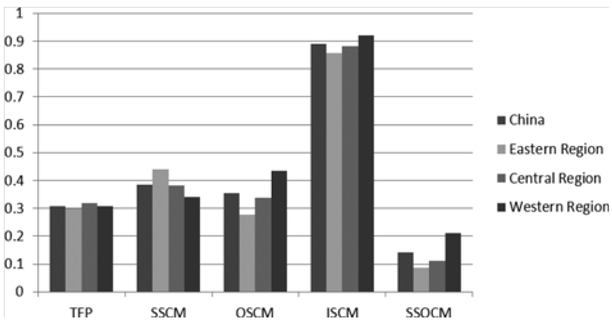

Table 1. China's Regional Construction Industry TFP and the Indicators of Industrial Market Structure (2007-2012)

region	year	province	TFP	SSCM	OSCM	ISCM	SSOCM
eastern regional	2007	Beijing	0.2830	0.3068	0.3500	0.7872	0.0264
	2007	Tianjin	0.3059	0.3577	0.4098	0.8357	0.0209
	2007	Hebei	0.3069	0.2698	0.4111	0.9022	0.1321
	2007	Liaoning	0.3453	0.2121	0.2905	0.8573	0.0530
	2007	Shanghai	0.2535	0.3000	0.2043	0.7777	0.0607
	2007	Jiangsu	0.3633	0.3201	0.0745	0.8695	0.0546
	2007	Zhejiang	0.3143	0.5158	0.0396	0.9288	0.0745
	2007	Fujian	0.3531	0.2712	0.2006	0.8776	0.0685
	2007	Shandong	0.3087	0.1902	0.2608	0.8488	0.1121
	2007	Guangdong	0.3571	0.2317	0.3374	0.7643	0.0791
	2007	Hainan	0.4595	0.2631	0.8567	0.9521	0.2177
	LL						
central region	LL						
	2012	Shanxi	0.3692	0.4238	0.3336	0.9212	0.0609
	2012	Jilin	0.2125	0.3856	0.1013	0.8620	0.0822
	2012	Heilongjiang	0.2805	0.3730	0.3791	0.8012	0.1248
	2012	Anhui	0.3031	0.5335	0.2873	0.8938	0.1121
	2012	Jiangxi	0.3329	0.5927	0.2903	0.9306	0.2424
	2012	Henan	0.3155	0.4442	0.1560	0.8904	0.0695
	2012	Hubei	0.3044	0.8130	0.3172	0.9070	0.1038
	2012	Hunan	0.2975	0.7405	0.3200	0.9425	0.1877
western region	LL						
	2012	Inner Mongolia	0.2423	0.5573	0.1120	0.9543	0.2848
	2012	Guangxi	0.3267	0.5677	0.6168	0.9558	0.1880
	2012	Chongqing	0.2882	0.5454	0.2130	0.9290	0.1136
	2012	Sichuan	0.3214	0.6258	0.2882	0.9261	0.1431
	2012	Guizhou	0.2854	0.5963	1.0000	0.8536	0.2113

2012	Yunnan	0.3146	0.3669	0.2863	0.9223	0.1324
2012	Tibet	0.2491	0.1581	0.4233	0.9765	0.5997
2012	Shaanxi	0.2659	0.9048	0.4594	0.9089	0.3671
2012	Gansu	0.2969	0.3944	0.3196	0.9388	0.1349
2012	Qinghai	0.3022	0.2842	0.7293	0.9467	0.1381
2012	Ningxia	0.3093	0.2943	0.3774	0.9631	0.1231
2012	Xinjiang	0.3183	0.5856	0.2901	0.9548	0.1605

Note: all the indicators were standardized. The original data are divided by the maximum value of the data, so that all the data are between 0 and 1. If there is a negative value in the original data, it should be combined with an appropriate positive number in all the original data, so that all data become positive, then the available data are obtained by dividing the maximum value of the data.

Fig. 3. Averages of Regional Indicators

China's regional construction industry TFP has first increased and then decreased. SSCM declined from the east to the west. OSCM, ISCM, SSOCM increased from the east to the west.

However, when only looking at Fig. 3, it is difficult to directly infer the relationship between TFP and the four coefficients.

4.3 Market Structure's Influence on China's Construction Industry TFP

In accordance with the theoretical hypothesis of market structure and the construction industry TFP, the four types of panel data models were established as follows. The data of Model One was from all the provinces of the China, while the data of Model Two, Model Three and Model Four came from eleven provinces in the eastern region, eight provinces in the central region and twelve provinces in the western region, respectively. Meanwhile, all the data were transformed logarithmically. Specific results are shown in Table 2.

First, we look at the estimation results of the models. In Model

Table 2. Influence of Market Structure on the Construction Industry TFP (dependent variable Ln (TFP))

	Model One	Model Two	Model Three	Model Four
C	-0.35** (-2.11)	-0.48*** (-9.12)	-0.44*** (-5.61)	-0.43 (-1.54)
Ln (SSCM)	0.20** (2.26)	-0.07 (-0.80)	-0.01 (-0.08)	0.20** (1.99)
Ln (OSCM)	-0.21*** (-2.89)	-0.003 (-0.13)	0.02 (0.28)	-0.37*** (-2.85)
Ln (ISCM)	0.41 (0.53)	0.80*** (2.96)	-0.79* (-1.91)	1.22 (0.85)
Ln (SSOCM)	0.18* (1.76)	0.03** (1.98)	0.11** (2.33)	0.15 (0.51)
R_2	0.70	0.83	0.79	0.65
D.W.	2.95	2.55	2.62	3.24
Hausman	23.39***	7.22	2.70	13.58***
LR	30.59***	20.30***	11.23***	7.85***
Model Selection	FE FE	RE FE	RE FE	FE FE
LLC	-17.33***	-8.67***	-6.45***	-9.74***
Fisher-PP	176.13***	53.90***	35.92***	79.56**

Note: (1) numbers in square brackets are values of T test; and (2) ***, **, and * refer to the significance at the 1%, 5%, and 10% level; (3) the Hausman test is an approach to test an individual random effect, while the LR test is an approach to test a time-fixed effect; (4) RE refers to random effect, and FE refers to fixed effect; (5) in the 'Model Selection' row, the first item of Model Selection refers to the selection of an individual direction effect and the latter item refers to the selection of time direction.

One and Model Four, the results of the Hausman test and LR test both rejected their null hypothesis significantly; individual direction and time direction both had fixed effects. In Model Two and Model Three, the result of the Hausman test is not significant, thus we could not reject the null hypothesis that individual direction had a random effect. While the result of LR test is significant, and time direction had fixed effect. Moreover, the residual stability of the four models was good without spurious regression. Overall, the fitting effects of the data of the eastern and central regions were better than those of the entire country and the western region.

Second, from the regression results, the influences of SSCM, OSCM and ISCM on TFP varied within the four regions. When looking at the entire country and the western region, SSCM and the construction industry TFP had a significant positive correlation. SSCM had a negative effect on TFP of the eastern and central regions, while the influences were weak. OSCM in the entire country and the eastern and western regions had a negative correlation with TFP. Of these, the eastern region did not pass the significant test, while OSCM in the central region had a positive effect on TFP. ISCM had positive effects on the construction industry TFP of the entire country and the eastern and western regions, but only the eastern region was significant. In contrast, ISCM in the central region hindered the increase of TFP. When tested over different regions, SSOCM and the construction industry TFP had a positive correlation: only the western region did not pass the significant test.

Based on the results listed above, we would conduct more deeply and systematically analyzing the interaction mechanisms of the four indicators on the construction industry TFP in the next section.

5. Systematic Analysis of the Spatial Difference ofthe Interaction Mechanisms of Market Structure in the Construction Industry TFP

Through this empirical analysis, it can be found that the interaction mechanisms of market structure in China's regional construction industry TFP show both similarities and unique characteristics, which reflect the common features of the current development of China's construction industry and unbalanced regional development.

When looking at the entirety of China, the ownership structure of the construction market has a significant negative impact on the Chinese construction industry TFP. This result shows that the state-owned economy is an important factor constraining productivity of the construction industry, as well as a concentrated reflection that the ownership reform of China's construction industry is not complete. Although state-owned enterprises have scale and technical advantages, they create a degree of monopoly, which is not conducive to the orderly development of construction market competition. To change this situation, we should actively promote the reform of state-owned enterprises, vigorously accelerate the reform of property rights, and encourage the development of a variety of ownership types. In contrast, scale structure and specialization structure have a certain degree of positive impact on TFP. In addition, industrial structure does not have substantial influence on the construction industry TFP. To some extent, this reflects that market monopoly does exist in civil engineering and house building engineering industries. In summary, for the entirety of China, the reform of state-owned enterprises need be continued, and this should be the future direction of construction industry development.

The construction industry TFP of the eastern region is mainly affected by industrial structure and specialization structure. The output ratio of building and civil engineering construction has a positive correlation with the construction TFP, which reflects that the eastern region has a competitive advantage in housing construction companies and railways, bridges and other civil engineering industry, and it should continue to accelerate the development of building and civil engineering. The ratio of general contracting enterprises to professional contracting enterprises also has a positive correlation with the construction industry TFP, which shows that the structure of the eastern division of labor is relatively reasonable. Generally, general contracting enterprises are large-scale comprehensive enterprises with strong comprehensive strength, while professional subcontractors have relatively small size, focusing on one or some related construction projects. Meanwhile, labor subcontracting enterprises are labor-oriented enterprises, which concentrate on improving labor force with a relatively large quantity but small size. These three types of enterprises have different specializations and functions, which forms the organizational structure of enterprise specialization. Currently, while there are a large number of general contractors in the eastern region, they still cannot meet the needs of the construction market. Therefore, the direction of future development in the eastern region of the construction market will be to continue to increase the number of general contracting businesses in that region.

The construction industry TFP of the central region is mainly influenced by specialization structure and industrial structure. The output ratio of building and civil engineering construction is negatively correlated with construction industry TFP, which is a concentrated reflection of irrational industrial structure of the central region. According to the national industry classification standard, construction industry is composed of building and civil engineering construction, construction and installation, architectural and other construction industry. Of these, building and civil engineering construction has advantages over the other three industries in scale, financial strength or technical strength. However, its productivity has a negative influence on TFP. Therefore, the formation of a scientific and rational industry structure is the key to improve TFP. At present, the development of building and civil engineering has progressed much faster than the other three industries, so we urgently need to moderately accelerate the development of the construction and installation, architectural and other construction industries, which should also be the future direction of development.

The construction industry TFP of the western region is mainly affected by ownership structure and scale structure. The output ratio of state-owned enterprises in the western region has a negative effect on construction industry TFP. This is because the economy of western region is relatively backward, and stateowned enterprises are mainly government-supported companies to promote the economic development. Thus, state-owned enterprises have formed a market monopoly, which inhibits the vitality of the construction market in the western region. Accordingly, the focus of future development is to encourage private and foreign-funded enterprises to enter the competition. Moreover, scale structure promotes the construction industry TFP in the western region. Large contracting enterprises could make full use of economies of scale and technological innovation. Therefore, the higher industrial concentration is, the more conducive it will be to improving construction industry productivity. Based on the negative influence of ownership structure and the positive effect of scale structure, the western region should encourage non-state-owned companies to diversify corporates ownership in construction industry and encourage largesized companies and mergers between small-sized companies to take advantage of economies of scale, which are both the future directions.

6. Conclusions

Our objectives for this research are threefold: to discover the reason for the low productivity of the construction industry; to reduce the differences in regional development throughout China; and to improve the overall productivity of the construction industries. We have used three different methods (the DEA– Malmquist index, the measurement for the market structure, and the panel data model) to measure the construction industry TFP and market structure, as well as to analyze the interaction mechanisms regionally from the perspective of space and industrial market structure. Looking at China as an example, we find that the traditional SCP paradigm of industrial economy can still be applied to the construction industry. Ownership structure has a significant negative impact on the construction industry TFP of the entire country and the western region, which is due to the incomplete restructuring of state-owned enterprises. To some extent, scale structure promotes the TFP of the entire country and the western region, which indicates that the higher the degree of industrial concentration, the more beneficial it is to improve the production efficiency of the construction industry. In contrast, industrial structure does not have a profound influence on the TFP of the entire country. However, industrial structure shows the opposite influence on the TFP of the eastern region and the central region, which indicates that the development of the building and civil engineering construction industries in our country is not balanced. In addition, specialization structure has a significant role in promoting the TFP of the entire country as well as the eastern and central regions, which means that continuing to increase the number of general contracting businesses is still the focus of development. Based on the diversity of the influences of market structure on the construction industry TFP among regions, we propose the future direction of construction industry in each region for policymaking and strategic decisions that may improve China's construction industry TFP.

From the perspective of industrial organization, the research method proposed in this study combines the methods of TFP measurement and of market structure and uses a panel data model to analyze the relationship between them. Thus, it achieves theoretical innovation in the research mode for the interaction mechanisms of construction industry productivity and considers space effects and similar samples divided by regions. In comparison with previous analysis methods, we add a spatial dimension to the analysis of factors influencing the construction industry productivity, which results in measures that are more reasonable and more in accordance with the actual situation. Moreover, the research methods presented in this study can be applied to other countries in which regional differences exist in the productivity development and specific market structure of the construction industry. Therefore, this study provides certain reference for some developing countries in which construction industry is a major pillar industry, although it is a case study in China. According to the SCP paradigm, it can also be used to analyze other industries' productivity interaction mechanisms, such as the manufacturing industry. What's more, in the terms of practical significance, we point out the future directions of the construction development for each region in China.

Furthermore, the current research has mainly focused on the measurement for construction industry productivity. Influence on the construction industry TFP has been mainly studied from a micro perspective, such as at the project or company level. Meanwhile, the influencing factors used to evaluate the construction industry TFP are non-systematic and too fragmented. This paper begins to study the interaction mechanisms of construction industry productivity from the perspective of space and industrial market structure. As the number of samples and the time dimension increase, future research should focus on implementing a phased comparative measure of the interaction mechanisms of market structure in the construction industry TFP to further improve competition in the construction industry. For example, the construction industry of a certain region can conduct a longitudinal comparison with itself in different periods (e.g., every 5 years) based on TFP. Moreover, according to the statistical data of the construction industry in different countries, it is worthwhile to determine which indicators can be replaced in the market structure of the construction industry.

Acknowledgements

The work was supported by the National Natural Science Foundation of China (No. 71102072, 71271143 and 71231006).

References

Allmon, E., Haas, C. T., Borcherding, J. D., and Goodrum, P. M. (2000). "US construction labor productivity trends, 1970-1998." Journal of Construction Engineering and Management, Vol. 126, No. 2, pp. 97-104, DOI: 10.1061/(ASCE)0733-9364(2000)126:2(97).

Caves, D. W., Christensen, L. R., and Herriges, J. A. (1984). "Consistency of residential customer response in time-of use electricity pricing experiments." Journal of Econometrics, Vol. 26, No. 1, pp. 179-203, DOI: 10.1016/0304-4076(84)90017-4.

Chau, K. W. (1993). "Estimating industry-level productivity trends in the building industry from building cost and price data." Construction Management and Economics, Vol. 11, No. 5, pp. 370-383, DOI: 10.1080/01446199300000041.

Chau, K. W. and Walker, A. (1988). "The measurement of total factor productivity of the Hong Kong construction industry." Construction Management and Economics, Vol. 6, No. 3, pp. 209-224, DOI: 10.1080/01446198800000019.

Chen, Y. and Iqbal, A. (2004). "DEA malmquist productivity measure: New insights with an application to computer industry." European Journal of Operational Research, Vol. 159, No. 1, pp. 239-249, DOI: 10.1016/S0377-2217(03)00406-5.

Chiang, Y. H., Tang B. S., and Leung, W. Y. (2001). "Market structure of the construction industry in Hong Kong." Construction Management and Economics, Vol. 19, No. 7, pp. 675-687, DOI: 10.1080/ 01446190110067046.

Denison, E. F. (1972). "Classification of sources of growth." Review of Income and Wealth, Vol. 18, No. 1, pp. 22-25, DOI: 10.1111/j.14754991.1972.tb00851.x.

El-Gohary, K. M. and Aziz, R. F. (2013). "Factors influencing construction labor productivity in Egypt." Journal of Management in Engineering, Vol. 30, No. 1, pp. 1-9, DOI: 10.1061/(ASCE)ME.19435479.0000168.

Fan, J. T. (2010). Market structure, performance, and competition policy of China's construction Industry, Shanghai University of Finance and Economics publishing, Shanghai.

Färe, R. S., Grosskopf, S., Norris, M., and Zhang, Z. (1994b). "Productivity growth, technical progress and efficiency change in industrialized countries." The American Economic Review, Vol. 87, No. 5, pp. 6683.

Färe, R., Grosskopf, S., and Lovell, C. A. K. (1994a). Production frontiers, Cambridge University Press, Cambridge.

Färe, R., Grosskopf, S., Lindgren, B., and Roos, P. (1992). "Productivity change in Swedish pharmacies 1980-1989: A non-parametric malmquist approach." Journal of Productivity Analysis, Vol. 3, No. 1, pp. 85-101, DOI: 10.1007/BF00158770.

GAO, J. Y. (2003). "A positive analysis on total factor productivity of Chinese construction industry." Journal of Shandong University of Architecture and Engineering, Vol. 18, No. 4, pp. 78-82.

Gollop, F. M. (1985). "Analysis of the productivity slowdown: Evidence for a sector-biased or sector-neutral industrial strategy," in W.J. Baumol and K. McLennan (Eds). Productivity growth and US competitiveness, Oxford University Press, Oxford.

Grifell-Tatjé, E. and Lovell, C. A. K. (1996). "Deregulation and productivity decline: the case of Spanish savings banks." European Economic Review, Vol. 40, No. 6, pp. 1281-1303, DOI: 10.1016/ 0014-2921(95)00024-0.

Hanna, A. S., Taylor, C. S., and Sullivan, K. T. (2005). "Impact of extended overtime on construction labor productivity." Journal of Construction Engineering and Management, Vol. 131, No. 6, pp. 734-739, DOI: 10.1061/(ASCE)0733-9364(2005)131:6(734).

Herbsman, Z. (1977). Developing of a mathematical model for estimating and updating of construction inputs.Technion, Haifa, Israel.

Hwang, B. G. and Soh, C. K. (2013). “Trade-Level Productivity Measurement: Critical Challenges and Solutions.” Journal of Construction Engineering and Management, Vol. 139, No. 11, DOI: 10.1061/ (ASCE)CO.1943-7862.0000761.

Hwang, B. G., Zhao, X., and Do, T. H. V. (2014). “Influence of tradelevel coordination problems on project productivity.” Project Management Journal, Vol. 45, No. 5, pp. 5-14, DOI: 10.1002/ pmj.21445.

Kane, A. R. (1980). “An examination of the factors influencing productivity in the highway.” Construction Industry. In Proceedings of the CIB W65 Third Symposium tin Organisations and Management of Construction. Dublin A, Vol. 1.

Keskin, B. Y. and Degirmen, S. (2013). “The application of data envelopment analysis based Malmquist total factor productivity index: Empirical evidence in Turkish banking sector.” Panoeconomicus, Vol. 60, No. 2, pp. 139-159, DOI: 10.2298/PAN1302139K.

Kumar, S. (2006). “A decomposition of total productivity growth: A regional analysis of Indian industrial manufacturing growth.” International Journal of Productivity and Performance Management, Vol. 55, Nos. 3-4, pp. 311-331, DOI: 10.1108/17410400610653255.

Levin, A., Lin, C. F., and Chu, C. (2002). “Unit root tests in panel data: asymptotic and finite-sample properties.” Journal of Econometrics, Vol. 108, No. 1, pp. 1-24, DOI: 10.1016/S0304-4076(01)00098-7.

Li, Y. M. and Tong, R. C. (2007). “DEA‘s application in the inputoutput tables and analysis of the construction industry.” Mathematics in Practiced and Theory, Vol. 37, No. 9, pp. 31-39, Available from http://www.cnki.com.cn/Article/CJFDTotal-SSJS200709005.htm.

Liu, B. S., Chen, X. H., Wang, X. Q., and Chen, Y. (2013a). “Analysis on the changing trend and influencing factors of TFP about the regional construction industry in China.” Systems Engineering Theory & Practice, Vol. 33, No. 4, pp. 1041-1048.

Liu, B. S., Wang, X. Q., Chen, Y., and Ying, H. S. (2013b). “Market structure of China’s construction industry based on the Panzar-Rosse model.” Construction Management and Economics, Vol. 8, No. 1, pp. 1-15, DOI: 10.1080/01446193.2013.817679.

Lorenz, T. (1906). “Beiträge zur Geologie und Palaeontologie von Ostasien unter besonderer Berücksichtigung der Provinz Schantung in China.” Zeitschrift der Deutschen Geologischen Gesellschaft, Issue 58, pp.53-108.

Lowe, J. G. (1987). “The measurement of productivity in the construction industry.” Construction Management and Economics, Vol. 5, No. 2, pp. 101-113, DOI: 10.1080/01446198700000010.

Maddala, G. S. and Wu, S. (1999). “A comparative study of unite root tests with panel data and a new simple test.” Oxford Bulletin of Economics and Statistics, Vol. 61, No. S1, pp. 631-652, DOI: 10.1111/1468-0084.0610s1631

Mahmood, A. and Afza, T. (2008). “Total factor productivity growth in east Asia: A two pronged approach.” European Journal of Economics, Finance and Administrative Sciences, Issue 14, pp. 93-113.

Malmquist, S. (1953). “Index numbers and indifferences surfaces.” Trabajos de Estatistica, Vol. 4, No. 2, pp. 209-242, DOI: 10.1007/ BF03006863.

National Bureau of Statistics of China (2008-2013). China statistical yearbook, China Statistics Press, 2008-2013. Available from http:// www.stats.gov.cn/tjsj/ndsj/

Ofori, G. (1996). “International contractors and structural changes in host country construction: Case of Singapore.” Engineering Construction and Architectural Management, Vol. 3, No. 4, pp. 271-288, DOI: 10.1108/eb021035.

Park, H. S., Thomas, S. R., and Tucker, R. L. (2005). "Benchmarking of construction productivity." Journal of Construction Engineering and Management, Vol. 131, No. 7, pp. 772-778, DOI: 10.1061/(ASCE) 0733-9364(2005)131:7(772).

Patricio, R. C., Jesus, C. P. A. V., and Jorge, A. P. (2012). "Evaluating the efficiency of the higher education system in emerging economies: Empirical evidences from Chilean universities." African Journal of Business Management, Vol. 6, No. 4, pp. 1441-1448, DOI: 10.5897/ AJBM11.1982.

Pearce, D. W. (2003). The social and economic value of construction: The construction industry's contribution to sustainable development, Construction Industry Research and Innovation Strategy Panel, London.

Reid, G. C. (1987). The theories of industrial organization, Blackwell Publishers, New York.

Shen, Z., Jensen, W., Berryman, C., and Zhu, Y. (2010). "Comparative study of activity-based construction labor productivity in the United States and China." Journal of Management in Engineering, Vol. 27, No. 2, pp. 116-124, DOI: 10.1061/(ASCE)ME.1943-5479.0000037.

Sonmez, R. and Rowings, J. E. (1998). "Construction labor productivity modeling with neural networks." Journal of Construction Engineering and Management, Vol. 124, No. 6, pp. 498-504, DOI: 10.1061/(ASCE)0733-9364(1998)124:6(498).

Stigler, G. L. (1956). Trends in employment in the service industries, National Bureau of Economic Research, Cambridge.

Stumpf, I. (2000). "Competitive pressures on middle-market contractor in the UK." Engineering Construction and Architectural Management, Vol. 7, No. 2, pp. 159-168, DOI: 10.1046/j.1365-232x.2000.00149.x.

Wang, X. Q., Chen, Y., Liu, B. S., Shen, Y. H., and Sun, H. (2013). "A total factor productivity measure for the construction industry and analysis of its spatial difference: A case study in China." Construction Management and Economics, Vol. 9, No. 1, pp. 1-13, DOI: 10.1080/01446193.2013.826371.

Wolff, E. N. (1981). "The accumulation of wealth over the life-cycle: A microdata analysis." The Review of Income and Wealth, Vol. 27, No. 1, pp. 75-96, DOI: 10.1111/j.1475-4991.1981.tb00193.x.

Wolgemuth, J. C., Latham, M. C., Hall, A., Chesher, A., and Crompton, D. W. (1982). "Worker productivity and the nutritional status of Kenyan road construction laborers." The American journal of clinical nutrition, Vol. 36, No. 1, pp. 68-78.

Xia, L. K. (2010). "How human capital and R&D investments influence TFP." Journal of Quantitative & Technical Economics, No. 4, pp. 78-94.

Xue, X., Shen, Q., Wang, Y., and Lu, J. (2008). "Measuring the productivity of the construction industry in China by using DEAbased Malmquist productivity indices." Journal of Construction engineering and Management, Vol. 134, No. 1, pp. 64-71, DOI: 10.1061/(ASCE)0733-9364(2008)134:1(64).

Yuan, X. L. and Zhang, B. S. (2009). "The determinants study of total factor productivity of China's commercial banks." Journal of Quantitative & Technical Economics, No. 04, pp. 93-104.

Zeng, S. X., Chen, H. M., and Tam, C. M. (2005). "Market structure of the construction industry of China." Architectural Science Review, Vol. 48, No. 4, pp. 367-376, DOI: 10.3763/asre.2005.4844.

Zhi, M., Hua, G. B., and Wang, S. Q. (2003). "Total factor productivity growth accounting in the construction industry of Singapore." Construction Management and Economics, Vol. 21, No. 7, pp. 707718, DOI: 10.1080/0144619032000056126.