Factors Affecting the Productive Efficiency of Construction Firms in Hong Kong

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Introduction

This study investigates the factors that affect the productive efficiency of construction firms in Hong Kong. Productive efficiency refers to the comparison of the volume of output to that of the resources used to produce the output. This comparison reflects the technological capability of a company. Not only will such a capability vary across different companies at any point in time, it will also change over time due to technological progress. This study attempts to measure the productive efficiency of construction firms and the rate of change of productive efficiency over time, and to explain the observed variations in productive efficiency across construction firms. Previous studies suggest size and capital intensity and the level of research and development as the key factors affecting the productive efficiency of a company. In addition to these factors, other factors investigated in this study include the degree of subcontracting and property cycles. The results of this can help contractors to improve their efficiency, and also assist policymakers in formulating strategies for advancing the technological capability of the entire construction industry.
Issues and motivation

The objectives of this study project are to:
1. measure the productive efficiency of construction firms in Hong Kong;
2. analyse the factors that affect the relative efficiency of construction firms; and
3. identify the determinants of changes in efficiency of construction firms over time.

The results of the study will shed light on the following unsolved important issues:
(a) Do economies of scale exist at the firm level?
(b) How does mechanisation affect the level and growth of efficiency in construction firms?
(c) Does subcontracting affect a contractor’s productive efficiency?
(d) Has the rate of technological progress in the construction industry been declining?
(e) How do property cycles affect the productive efficiency of construction firms?

(a) Do economies of scale exist at the firm level?

Previous studies in other sectors have suggested that larger firms are more efficient. However, the scale effect will gradually disappear as firm size increases. This study tests whether firm level economies of scales exist in the construction industry, and estimates the size of firms in which the scale effect will be exhausted. Such a turning point is important for the estimation of the optimal size of a construction firm and therefore can assist decision makers in formulating their business strategies.

(b) How does mechanisation affect the level and growth of efficiency in construction firms?

The answer to this question provides hints on the substitutability between capital and labour, and whether an increase in capital investment can improve the productive efficiency of construction firms.

(c) Does subcontracting affect a contractor’s efficiency?

The extensive practice of subcontracting is a very unique phenomenon in the construction industry. There has been a long debate over whether subcontracting is beneficial to the efficiency of the construction industry. However, there has been very little empirical study on this issue. The results of this study should contribute to our understanding of how this unique phenomenon affects the productive efficiency of the construction industry.

(d) Has the rate of technological progress in the construction industry been declining?

This is another long debate issue. The results will shed light on Chau’s (1993) argument based on the catching up hypothesis. The results would also have significant policy implications, as the catching up hypothesis suggests that without investment on research and development, the rate of technological progress would decline once the technological level of the industry has caught up with those in the more technologically advanced economies.
(e) How do property and construction cycles affect the productive efficiency of construction firms?

This study tests the widely accepted belief that volatility in the demand for construction work has a negative impact on productive efficiency. Furthermore, during property booms, developers will compress the construction program to lower the holding cost, thereby resulting in the use of less efficient techniques and higher material wastage, which will also lead to a decline in productive efficiency. The high wastage of material will also have a significant impact on the environment, and thus the results would have significant policy implications on environmental management.

Some of the above issues have been researched for the entire economy or other industries in other parts of the world. However, the empirical results have been mixed. As far as the authors know, there has been no similar empirical research done on the construction industry. This empirical research will not only shed light on issues related to productive efficiency in the construction industry, but some of the findings can be generalised in other industries as well. Besides academic significance, the results of the research are also important for business decision makers such as contractors, building owners, property investors, and practising professionals. The results will also have important implications for the Hong Kong Government when it comes to formulating an appropriate policy for Hong Kong's construction industry, of which the government is the largest single client.

Evaluation of Firm Level Productive Efficiency

The data envelopment analysis (DEA) is used to estimate the productive efficiency of construction firms in different trade groups of the construction industry. The technique was first proposed by Farrel (1957) later further developed and generalised by other researchers (see, for example, Charnes, et. al., 1994). The approach is non-parametric and therefore does not assume a specific functional form for the underlying production function. Input and output data of a production unit (e.g. a firm) are used to estimate the most efficient frontier. The relative productive efficiency of each production unit (PU) is then evaluated in relation to the most efficient frontier.

For illustration purposes, consider the simple case where all PUs use two of input (K, L) to produce one output (Q). The relationship between inputs and outputs of these PUs can be plotted on a two-dimensional plane with the L/Q and K/Q as the X-axis and Y-axis, respectively, as follows.
Each point on the graph represents the quantity and mix of inputs used by a PU to produce one unit of output. Curve SS' represents the most efficient production technology that can be achieved (or the production frontier) at any point in time. The observations that fall on SS' are the best practice PUs. Technological progress over time is represented by the movement of the SS' towards the origin.

The productive, or production, efficiency ratio of a PU represented by point P is defined as:

\[
ER_P = \frac{OR}{OP}
\]

The productive efficiency ratio \( ER_P \) reflects the productive efficiency of observation P relative to a PU R (could be real or hypothetical) on the production frontier with the same input mix. The closer the observation P is to the frontier SS', the larger the value of \( ER_P \) (i.e. productive efficiency). To avoid the problem of specifying the functional form of the production frontier, SS' is estimated by joining the observed best practices (or the most efficient PUs) by linear line segments. To complete the production frontier, two line-segments are projected from the observations that use the minimum amount of each input to infinity. That is, two extra hypothetical observations represented by \((0, \infty)\) and \((\infty, 0)\) that lie at the two end-points of the production frontier are added to the set of observations. The productive efficiency of any observation \( P_h \) can be evaluated by comparing the distance of \( P_h \) from the origin \( (OP_h) \) to a hypothetical observation \( P_h' \) on SS' that uses the same input mix as \( P_h \) \( (OP_h') \). That is:

\[
ER_{P_h} = \frac{OP_h'}{OP_h}
\]

Let A denote the set of observations \( P_1, P_2, \ldots, P_n \) and the two hypothetical observations \((\infty, 0)\) and \((0, \infty)\). Let \( P_i(x_{i1}, x_{i2}) \) denote ith PU of set A, and \( P_h = (x_{h1}, x_{h2}) \) denote the PU to be evaluated. \( P_h \) can be expressed as the weighted average of two observations on the frontier. That is:
\[
\begin{align*}
\beta_1 x_{1i} + \beta_2 x_{1j} &= x_{1k} \\
\beta_1 x_{2i} + \beta_2 x_{2j} &= x_{2k}
\end{align*}
\]  

(3)

where $\beta_1$ and $\beta_2$ are variables in the equations.

Let $\beta_1'$ and $\beta_2'$ represent the solutions to the equations. Real positive solutions exist for $\beta_1$ and $\beta_2$ only if the line $OP_h$ intersects the line-segment on the production frontier $SS'$. The line-segment joining $P_iP_j$ is part of $SS'$ if and only if:

\[
\beta_1' + \beta_2' \geq 1 \quad \forall P_h \text{ in } A
\]

(4)

That is, all observations must lie in the northeast direction of $SS'$. The larger the value of $\beta_1' + \beta_2'$, the further away the $P_h$ is from $SS'$, and therefore the less efficient the PU. Furthermore, $P_h$ is on the production frontier if and only if $\beta_1' + \beta_2' = 1$.

The productive efficiency ratio (ER) of $P_h$ is therefore:

\[
ER_h = \text{Max} \left( \frac{1}{\beta_1' + \beta_2'} \right) \quad \forall \text{ segment } P_iP_j \in SS'
\]

(5)

This approach can be generalised into more than 2 inputs and 1 output using the DEA approach. Consider that there are $n$ m-input-k-output PUs. Each unit consumes different amounts of $m$ different inputs to produce $k$ different outputs. The inputs and outputs can be expressed with matrices $X$ and $Y$, respectively as follows:

\[
X = \begin{bmatrix}
x_{11} & x_{12} & \cdots & x_{1m} \\
x_{21} & x_{22} & \cdots & x_{2m} \\
\vdots & \vdots & \ddots & \vdots \\
x_{ni} & x_{n2} & \cdots & x_{nm}
\end{bmatrix}
\]

(6)

\[
y_{ij} \geq 0 \text{ represents the } j\text{th input used by the } i\text{th PU where } i=1,2,\ldots,n \text{ and } j=1,2,\ldots,m.
\]

\[
Y = \begin{bmatrix}
y_{11} & y_{12} & \cdots & y_{1k} \\
y_{21} & y_{22} & \cdots & y_{2k} \\
\vdots & \vdots & \ddots & \vdots \\
y_{ni} & y_{n2} & \cdots & y_{nk}
\end{bmatrix}
\]

(7)

\[
y_{ir} \geq 0 \text{ represents the } r\text{th output produced by the } i\text{th PU where } i=1,2,\ldots,n \text{ and } r=1,2,\ldots,k.
\]
The evaluation of ER can be formulated as a linear programming problem as follows:

$$\hat{\theta} = \min_{\theta, \lambda} \theta$$

s.t. $\lambda Y \geq \hat{Y}$

$$\theta \hat{X} - \lambda X \geq 0$$

$\lambda \geq 0$

where, $\lambda$ is the matrix with $n$ variables i.e. $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_n)$

$\hat{X} = (x_{i1}, x_{i2}, \ldots, x_{im})$ and $\hat{Y} = (y_{i1}, y_{i2}, \ldots, y_{ir})$ are vectors with components $x_{ij}$ and $y_{ir}$, for some $i$, $1 \leq i \leq n$, representing observed values of inputs ($j = 1, 2, \ldots, m$) and outputs ($r = 1, 2, \ldots, k$) for observation $i$, the observation being evaluated. The solution $\hat{\theta}, (0 \leq \hat{\theta} \leq 1)$ is the efficiency ratio (ER) of observation.

For the purpose of this study, a construction firm is modelled as a 4-input-1-output PU. The four inputs considered in this study are labour, capital, materials, and overhead.

Data and Sources

The data required to solve the linear programming problems are the inputs and outputs of the PUs. Since only aggregated data at the 4-digit trade level are available, a PU defined as all construction firms within the same 4-digit HSIC (Hong Kong Standard Industrial Classification). The data are not published but can be purchased from the Census and Statistics Department (CSD). The data has been available since 1981. The inputs include capital, labour, and two types of intermediate inputs (i.e. construction materials and office overhead expenses). Labour input is measured as head counts (including direct employees, owners, unpaid family workers, and labour only subcontractors). Capital input is measure by the mid-year value of fixed assets owned by the company plus the capitalised cost of rents paid for hiring fixed assets. Capital input is deflated by the unit value index of retained import of capital goods (available from CSD). Intermediate inputs are measured by payments for construction materials and other sundry supplies. The former is deflated by the Material Cost Index (available from the Architectural Services Department) and the latter by the Price deflator for Private Consumption Expenditure (available from the CSD). Output is measured by the total value of work done less payments to fee subcontractors to avoid double counting. The deflator for construction output is derived from the private and public sector tender price indices and other data. The details of the construction of the index are given in Chau (1990). The data for the construction of the index is available from the two major private sector quantity surveying firms (i.e. Levett and Bailey Chartered Quantity Surveyor and Davis, Langdon and Seah Hong Kong Limited), the Buildings Department, and the CSD. A more detailed discussion of the construction input and output price deflators can be found in Chau (1998).

There are altogether 41 sub-trade groups (PUs) in the construction industry. Input and output data for all the PUs for the 15 observation years have been pooled together and
the production efficiency ratio of each PU in each year relative to the overall efficiency frontier for the entire set of observations, which consists of 615 observations, are evaluated using the DEA method.

Factors Affecting Productive Efficiency in the Construction Industry

Based on the results of previous studies, we have proposed four major factors that affect the production efficiency of a PU in the construction industry at any point in time. They are capital to labour ratio, firm size, degree of subcontracting, and the proportion of intermediate inputs. In addition, ER, on average, may grow over time as a result of the catching-up process. Such growth is not steady and may be impacted by the property cycle. These factors are discussed in more detail below.

Capital to Labour Ratio

The capital to labour ratio indicates whether a PU is relatively capital intensive or labour intensive. While a higher capital to labour ratio suggests a higher degree of mechanization, production efficiency may not necessarily be higher as a result. This is especially true in the construction industry, where the degree of repetitiveness is small, rendering mass production techniques less effective. The difficulty of substituting capital for labour in the construction industry is well discussed in Poe, et al (1988). Although their discussion is concerned mainly with heavy engineering construction, such as excavation work, similar problems have also occurred in other subsectors of the construction industry.

More importantly, a higher level of fixed assets is more likely to be associated with a higher level of idle capacity, since the stock (rather than flow) concept is used for measuring capital input. Due to fluctuating workloads in the construction industry, the stock of fixed assets owned by a PU is unlikely to be fully utilized at all times. It is likely that idle capacity would increase as the total stock of fixed assets increases. This idling of fixed assets seems unavoidable because construction companies have to maintain a certain level of fixed assets to satisfy pre-qualification requirements to bid for larger public sector contracts. Besides, construction companies cannot predict future demand and work loads precisely. On the other hand, labour inputs are deployed in a much more flexible way in the construction industry. The use of casual daily-wage labour and labour only sub-contractors can minimize idle labour under uncertain workloads. Therefore, we expect that all other things being equal, the production efficiency is lower for the PUs with a higher ratio of stock of fixed assets to labour. It should be noted that the lower ER of the more capital-intensive firms at any point in time does not necessarily imply that the growth rates of the ER in these firms are slower (see below).

Firm Size

Whether larger firms can produce more efficiently than smaller firms is an empirical question. However, previous studies have suggested that economies of scale exist at the project level (Chau and Walker, 1994c; Chau, et al, 1996). Since large projects are often done by large firms, it is likely that economies of scale also exist at the firm level. The relationship between economies of scale and the U-shaped average cost curve has been well discussed by Alchian (1977). The existence of economies of scale at the firm
level were also suggested by McClenahen (1997) and Feiger (1988). Larger firms may be more efficient, since they are likely to be technologically more advanced and more systematically managed, have lower resource and finance costs due to better market and bargaining power, face fewer competitors, and are in a better position to diversify risk. In Hong Kong large companies tendering for public sector projects also benefit from the licensing/pre-qualification system, which essentially serves as an artificial barrier to entry into the public sector market. However, there is a natural limit to which the production efficiency can be improved through increasing the firm size. When a company becomes too big, it becomes less flexible due to the large bureaucratic system in place, encouraging inertia and resistance to change. Company politics are often counterproductive, and are likely to be more serious in very large companies. Thus, if economies of scale exist at the firm level, it will be exhausted up to a certain point. Otherwise, firms will grow indefinitely through mergers and acquisitions; and all firms will eventually be replaced by one single “super firm” in the industry. This is certainly not the case in the construction industry. Due to the problems of giant firms discussed above, the law of diminishing returns will operate and constrain the scale effects at the firm level. Therefore, we expect that economies of scale exist at the construction firm level (i.e. the ER of larger firms are higher than those of the smaller firms, *ceteris paribus*). However, this scale effect will diminish as a firm’s size increases up to a certain point where economies of scale will be exhausted, and beyond this point firm size will experience diseconomies of scale.

The Degree of Subcontracting

Subcontracting is a very common practice in the construction industry. The subcontracting phenomenon has attracted the attention of many researchers who have undertaken studies from many different angles. Examples of such work include Eccles (1981a, 1981b), Winch (1989), Chau and Walker (1994), Chau, Lai, and Wong (1994), Houston (1996), Tregaskis (1997), Debrah and Ofori (1997), and Nishiguchi and Brookfield (1997). It is generally believed that extensive subcontracting creates management problems that impact on efficiency (Kellogg, *et al.*, 1981, Genesan, 1984). These management problems are likely to lead to inefficiency. While this argument seems to be plausible, it is difficult to justify in economic terms, because the main contractors have the option not to subcontract. Since the main contractors subcontract part of the work voluntarily, they must have an economic reason for doing so (Chau and Walker, 1994).  

The main contractors do not necessarily possess all the specialized resources required to complete a project. As a result, parts of the project are often subcontracted out to smaller firms who can perform the tasks more efficiently. To what extent will a main contractor subcontract work out? Standard neo-classical economics analysis suggests that the main contractor will continue to subcontract up to the point where it is equally efficient for the next additional fraction of the project to be performed by either the main contractor or a subcontractor. Beyond this point, the main contractor can perform the tasks more efficiently than other subcontractors. For the same reason, the subcontractor will subcontract its work out to some other sub-subcontractors who can perform the task more efficiently until no other sub-subcontractors can perform more efficiently than this subcontractor. The chain of subcontracting will end when it is no longer worthwhile to

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1 Chau and Walker suggested that subcontracting can be seen as an efficient institutional arrangement that minimize transaction costs.
subcontract further (Chau and Lai, 1994). That is the lowest level subcontractors can perform the task more efficiently than any higher level sub-contractors.

At this level, the degree of subcontracting is zero. The production efficiency is also the highest, since there is no part of the work that can be performed by other subcontractors more efficiently. This argument can be extended to other levels of subcontractors. Since the un-subcontracted works must be more difficult to perform than those that are subcontracted out, the main contractors that undertake such work will appear to have lower production efficiencies. Furthermore, the resources that are deployed to perform the un-subcontracted work also include the management and coordination of different subcontractors that are not taken into account in the output measure. Therefore, the higher the proportion of the work that is subcontracted, the lower the productive efficiency of the PU will be in performing the un-subcontracted work. This argument is applicable to the PUs at the firm level or the groups of firms at the 4-digit level..

The Level of Material Consumption

The major component of intermediate input is construction materials. The degree of material wastage is a function of availability of material storage space, site management, and the speed of construction. In Hong Kong, most construction sites are very congested; and management of materials wastage is often a problem. The more material intensive the project, the more serious the problem will be. Moreover, in Hong Kong, material costs have not grown as fast as labour costs, so very little attention has been paid to minimizing material wastage. Since labour costs are a lot higher than material costs, the net savings (net of additional labour cost) from any effort to reduce material wastage is often limited, and thus the resources expended to reduce material wastage are often not justified economically. Therefore, the PUs in the construction industry that consume a higher proportion of intermediate input (construction material) will experience higher material wastage and are likely to be less efficient.

This is particularly true in Hong Kong, where property prices are high. High property prices imply that time is a very critical factor in property development, as the opportunity cost of locking capital up in a development project is very high. Speeding up the period of construction will result in a substantial savings in the opportunity cost of tied up capital. It is often economical to speed up construction even if it results in increased material wastage. Time is so critical that developers would prefer shorter construction durations even though they may result in more material wastage. Therefore, we expect that a higher level of material consumption is associated with a lower level of production efficiency, ceteris paribus.

Growth in Productive Efficiency over Time - The Catching Up Process

Previous studies have suggested that the production efficiency of the Hong Kong construction industry has increased over time (Chau and Walker, 1988, 1990), (Chau, 1993, 1998). There are three main sources of this production efficiency improvement: enhancement of labour quality due to investment in education, industry level economies of scale, and technological progress.

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2 In Hong Kong, construction costs are approximately 30%-40% of property prices, even after the Asian Financial Crisis. Before the crisis, construction costs were as low as 10% of property prices.
Education

The physiology of human beings has not changed significantly for thousands of years. The ability of the people to produce, however, has greatly increased. The major reason for this increase has been the progress of knowledge, technology, and human capital investment (i.e. education).

Although public education spending by the Hong Kong Government did not increase substantially over the observation period, the education level of Hong Kong’s labour force has increased quite significantly as Hong Kong’s economy develops. As the economy developed, more people could afford to spend more money to educate their children due to increases in income.

Besides tertiary education in local universities and colleges, the Vocational Training Council (VTC) and the Construction Industry Training Authority (CITA) have also provided training and apprenticeships for people in the industry at different levels. Furthermore, overseas education and training offered by local companies have provided substantial supplements. Increasing the number of qualified professionals and skilled labour through education and training can therefore improve the overall efficiency of the construction labour force.

Industry Level Economies of Scale

The production efficiency of an industry will increase as output volume rises due to specialization. The volume of output in the observation period has increased significantly. The output in 1996 is almost 3 times that of 1981. More specialization is possible with a larger market due to a higher demand for specialist works.

Technological Progress

Technology is one of the key sources of increases in productive efficiency over time. Advancement of productivity is closely linked with technological progress and economic development. The development of technology permeates all factors of production: labour, material, and machinery.

Although construction techniques in Hong Kong have greatly improved over the decades, the industry has been relatively slow in implementing new technologies when compared to other hi-tech industries. Improvements in production efficiency in the construction industry as a result of technological progress have not been very noticeable, especially over a short period of time. However, over a longer time horizon, the increase in production efficiency can be detected (Chau, 1993, 1998).

The major sources of technological progress in most developed countries are from Research and Development (R&D). This, however, has not been the case in Hong Kong. Since Hong Kong has been technologically less advanced compared to other developed countries such as the US and Japan and many European countries, the major source of technological progress in the construction industry has been diffused from other countries. Technology diffusion from other countries often takes the form of imported new plants, equipment and new materials, use of expatriate professionals, and the participation of overseas contractors. Technology diffusion in Hong Kong has been
greatly facilitated by the free trade policy adopted by the Hong Kong Government. There are no import taxes and tariffs. Hong Kong's construction industry is one of the freest construction industries in the world. Local contractors are not protected in any way from foreign competition. These foreign contractors are often large international contractors. They have brought in new technology and a modern approach to organization and management. At the same time, local contractors are forced to learn to improve their efficiency when facing foreign competition. Thus, the production efficiency of local firms has also improved. As a result, the technological capability of the entire construction industry has improved significantly.

R&D have been ignored to a large extent in Hong Kong's construction industry. Although this is not a major problem during the catching up process, as improvements in production efficiency could rely upon imported technologies, it will eventually become a serious problem towards the end of the catching up process. As the technology gap between Hong Kong and other developed countries narrows, it will become more difficult to improve production efficiency through technology diffusion, and the rate of growth in production efficiency will slow down. In Hong Kong, expenditure on research and development in the construction industry is still negligible (Chau, 1998). Therefore, while we expect the production efficiency of Hong Kong's construction industry to grow over time, the rate of growth is expected to slow down gradually.

Capital Investment

Another source of increase in production efficiency over time is through investment in capital. Capital intensive firms are more likely have a faster rate of growth in production efficiency through mechanization, despite their lower level of production efficiency due to idle capacity. Capital intensive firms are also more likely to advance their production efficiencies through the use of imported new plants and machinery. Therefore the growth rate of the firms with a higher capital-to-labour ratio is likely to be faster.

Property Cycles

The growth in production efficiency does not follow a smooth path. While part of the fluctuations in the growth of production efficiency could be due to measurement errors and unknown reasons, we believe the cyclical fluctuation in property prices has a significant role to play in explaining the short-term fluctuations of the production efficiency in Hong Kong’s construction industry.

In previous sections, we have discussed why the level of consumption of intermediate input will impact the production efficiency of the PUs in the construction industry. We will extend the argument further to explain the fluctuation of production efficiency. Due to high property prices (relative to construction cost), developers are willing to trade off time for production efficiency. Their willingness to trade off increases as property prices increase are due to the time cost of the capital locked up in development projects increasing with higher property prices. Therefore, we expect that declines in production efficiency will be higher during property booms, and lower during property slumps. Since the efficiency lost due to the compression of construction programs often takes the form of higher material wastage, the effect of the property cycle on the production efficiency is not uniform across all PUs. The PUs that consume a higher level of intermediate input will be affected more seriously by property cycles. Thus, we expect that the movements of property prices have a negative impact on the growth rate of the production efficiency in the construction industry, while the impact is higher for those subsectors of the
construction industry that use a higher proportion of intermediate inputs.

Empirical Tests and Results

The factors affecting the efficiency of the construction industry discussed in the previous sections can be tested by estimating the following equation:

\[ ER = b_0 + b_1 \cdot KL + b_2 \cdot SIZE + b_3 \cdot SIZE^2 + b_4 \cdot PFSC + b_5 \cdot PFSC^2 + b_6 \cdot PM + b_7 \cdot PM^2 + b_8 \cdot T + b_9 \cdot T^2 + b_{10} \cdot T \cdot CPP \cdot PM + b_{11} \cdot T \cdot KL \]  

(9)

where \( ER \) is then productive efficiency ratio of a 4-digit sub-trade group, \( KL \) is the capital-to-labour ratio, \( SIZE \) is the average size of firm in the sub-trade group, \( PFSC \) is the degree of sub-contracting, \( PM \) is the proportion of intermediate input to output, \( T \) is time in year; \( CPP \) is the annual percentage of changes in the property price level of Hong Kong, and \( b_i \)'s are coefficients to be estimated.

\( ER \) is estimated with the DEA model described above using the input and output data of the 4-digit trade groups. \( SIZE \) is measured in terms of average total number of persons directly engaged (sum of the number of employees, employers, and unpaid family workers) per firm of the 4-digit trade group. \( PFSC \) is measured as the ratio of the value of subcontracted work (value of work done by fee subcontractors) to the total value of work done. \( PM \) is measured as the ratio of total expenditure on intermediate input to gross output. Property price level is the average change in property price indices constructed by the Rating & Valuation Department (RVD) of different types of property weighted by the stock of each type of property.

Based on the previous discussions, the expected signs of the estimated coefficients are show in Table 1. The squared terms of \( PFSC \) and \( PM \) are added to test for linearity.

Table 1: Expected Signs of Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Expected sign of Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>KL</td>
<td>-ve</td>
</tr>
<tr>
<td>SIZE</td>
<td>+ve</td>
</tr>
<tr>
<td>SIZE^2</td>
<td>-ve</td>
</tr>
<tr>
<td>PFSC</td>
<td>-ve</td>
</tr>
<tr>
<td>PFSC^2</td>
<td>?</td>
</tr>
<tr>
<td>PM</td>
<td>-ve</td>
</tr>
<tr>
<td>PM^2</td>
<td>?</td>
</tr>
<tr>
<td>T</td>
<td>+ve</td>
</tr>
<tr>
<td>T^2</td>
<td>-ve</td>
</tr>
<tr>
<td>T \cdot CPP \cdot PM</td>
<td>-ve</td>
</tr>
<tr>
<td>T \cdot KL</td>
<td>+ve</td>
</tr>
</tbody>
</table>

Results and Discussions

\[3\] Since a majority of the total stock of all private properties are residential units, the property price index is dominated by the residential price indices.
The results of estimating Equation (9) are shown in Table 2. All coefficients are of the expected sign and significant at the 1% level. The DW statistics show no sign of autocorrelation.

The coefficient of $SIZE$ is positive suggesting firm level economies of scale. However, such scale economies will be exhausted up to a certain size, as indicated by the negative sign of $SIZE^2$.

The coefficients of both $PFSC$ and $PM$ are both negative, confirming our argument about the effects of subcontracting and the proportion of intermediate inputs on production efficiency. However, such a relationship is not linear as indicated by the significant squared terms. The coefficients of both of the squared terms are positive, which suggests that the negative impact on production efficiency declined as the variables increased.

The coefficient of $T$ is positive. This suggests that the productive efficiency of construction firms has increased over the period of observation. However, the coefficient of $T^2$ is negative and significant, which means that the rate of increase in production efficiency has decreased. This confirms that the growth of technical efficiency over time has declined due to the narrowing of the technology gap between Hong Kong and other developed countries. The continuing lack of R&D in Hong Kong’s construction industry means that growth in productive efficiency will continue to slow down in the future.

The coefficient of $T\cdot CPP\cdot PM$ is negative and significant at the 1% level. This supports our argument about the negative impact of property prices on the growth of production efficiency in the construction industry. Moreover, this effect is stronger for PUs with a higher proportion of intermediate input. This provides evidence that supports the argument that developers trade off production efficiency for a shorter project duration during property booms.

The coefficient of $T\cdot KL$ is positive and significant at the 1% level, which suggests that the growth in production efficiency is higher for the more capital intensive firms, although their levels of production efficiency are lower for each year compared to the less capital intensive firms. This is also consistent with many previous studies that have suggested that an increase in the capital-to-labour ratio is one of the major sources of growth in productivity (Chau, et al, 1990b, 1994c).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
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<tr>
<td>KL</td>
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<td>SIZE</td>
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<tr>
<td>SIZE^2</td>
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<tr>
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<tr>
<td>PM</td>
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<td>-7.654</td>
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<tr>
<td>PM^2</td>
<td>1.801</td>
<td>6.269</td>
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<td>T</td>
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<tr>
<td>T^2</td>
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<tr>
<td>T\cdot CPP\cdot PM</td>
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<td>-2.750</td>
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### Table

<table>
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<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>t-Statistic</th>
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<tbody>
<tr>
<td>T-KL</td>
<td>7.710×10^{-4}</td>
<td>9.817</td>
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Number of observations: 651  
Adjusted $R^2$: 0.319  
F-Statistics: 28.697  
DW-Statistics: 1.903

Note: All coefficients are significant at the 1% level.

### Conclusion

This study provides empirical evidence for a number of long debated issues in the construction industry. First, the productive efficiency of more capital intensive firms is lower due to difficulties in maintaining a high utilization rate of the plant and machinery. However, the productive efficiency of the more capital intensive firms tends to grow at a faster rate over time. Second, economies of scale exist at the firm level, but the scale effect will be exhausted at some point. This is consistent with the U-shape average cost curve. Third, firms with a higher degree of subcontracting tend to have a lower productive efficiency since the subcontractor must have higher productive efficiency to perform the subcontracted work. The main contractor's productive efficiency in undertaking the un-subcontracted work will be lower than that of the subcontracted work. Fourth, material intensive firms have a lower productive efficiency due to the problem of managing material wastage in congested sites in Hong Kong and the relatively low cost of construction materials in relation to other inputs. Fifth, the property cycle has a negative impact on the productive efficiency of construction firms, in particular those firms with higher levels of material consumption due to the compression of construction duration during property booms. Sixth, the rate of growth of productive efficiency has been declining, which is a sign of the end of the catching-up process.

### References


