Shadow Factor Price Convergence and the Response of Chinese State-Owned Construction Enterprises to Reform

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A generalized (nonminimum or shadow) cost function is used to evaluate the response of Chinese state-owned construction enterprises to economic reforms from 1985 to 1991. Generalized cost function estimates are used to calculate the variances of the shadow factor price ratios that characterize price efficiency, and these variances are regressed against reform variables to determine whether convergence took place. There is some evidence of improved technical efficiency, and competitive bidding reforms appear to have had some effect in improving factor price efficiency. However, there is no general evidence for the convergence of factor price inefficiency, and the general response to reform is either negative, insignificant, or inconsistent. J. Comp. Econom., August 1995, 21(1), pp. 54–81. University of Nevada, Reno, Nevada 89557-0016. © 1995 Academic Press, Inc.


1. INTRODUCTION

Since the start of systematic industrial reform in China during the mid-1980’s, numerous studies have examined Chinese industrial statistics and concluded that Chinese state enterprises were improving their productive efficiency at a respectable rate. It is therefore puzzling that Chinese state-

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2 Chen et al. (1988b), for example, estimate multifactor productivity growth rates between 4.8% and 5.9% per year from 1978 to 1985; Jefferson et al. (1992) revised these estimates to 2.4% per year by accounting for increased material inputs. In a study of the iron and steel industry, Jefferson (1990) estimates a similar rate of 2.5% productivity improvement per year.
owned enterprises are experiencing enormous difficulties at present even as the Chinese aggregate economy is growing rapidly, that approximately half of the state’s enterprises are officially admitted to be losing money, and that drastic enterprise reforms are being discussed at the highest levels of the Chinese Communist Party.

Most econometric studies have focused on technical efficiency, or multifactor productivity, to measure the impact of economic reform on the behavior and performance of Chinese enterprises. Using multifactor productivity to measure the impact of reform is problematic, however, because reform is likely to also induce changes in product quality or in the composition of output towards higher-valued goods. This makes identification of multifactor productivity difficult. Furthermore, it is also difficult to separate improvements in technical efficiency due to increased contacts with Western technologies, particularly when measures of cross-firm price differences are unavailable. In sum, it is not at all clear that measurements of improved multifactor productivity are enough to imply that state-owned enterprises are being managed more efficiently.

The purpose of this study is not to provide explanations for the relative deterioration of Chinese state enterprises, which are available elsewhere. Instead, this study focuses on how econometric studies might better identify improvements in enterprise behavior. While improved multifactor productivity may yield some information, this study concerns itself primarily with factor-price efficiency, the minimization of costs associated with a given level of output. It is presumed that decision-makers in the socialist enterprise maximize utility over a wide range of objectives subject to constraints not faced by the traditional profit-maximizing firm, and that successful reform increases the relative weight given profit in the objective function. Because reforms are partial, and therefore do not completely eliminate nonprofit motives or binding constraints, the marginal revenue products or shadow prices for inputs may not converge toward their observed factor prices; however, as nonprofit motives decrease in relative weight, the dispersion of inefficiency, as measured by the variances of the ratios of shadow to observed prices, should diminish.

The first part of this study builds a static model of utility maximization in which profit is only one of many objectives. This model explains why the shadow price ratio may differ from unity and predicts how both it and its variance should respond to economic reforms that strengthen the profit motive.

Naughton (1992), for example, has considered the effect of increased competition in eroding state enterprise profits. Parker (1994b) has suggested that state enterprises lack a selection mechanism to weed out poor performers. Stepanek (1991) has argued that state enterprises still are not overly concerned with costs, quality, or customers even after a decade of reform. Also, see Parker (1995) for a discussion.
After describing the data set, the paper then describes the actual estimation of convergence using the generalized cost function method, which directly estimates relative shadow price ratios, and then proceeds to show how the variance of the shadow price ratios can itself be estimated and tested for response to reform. While relative shadow price ratios can be directly estimated in the generalized cost function, their variances must be calculated from the estimates. Once these variances are calculated, they can be regressed against reform variables to test whether the dispersion of shadow price ratios has decreased in response to reform.

Most studies of Chinese economic reform have concerned themselves with manufacturing industries. This study looks instead at the Chinese construction sector, in which products are slightly more homogeneous and material inputs are less likely to be counted a multiple number of times. Accounting for over 8% of total social product and 10% of the nonagricultural workforce in 1991, construction is the third largest sector, behind manufacturing and agriculture, in the economy of the People’s Republic of China. After Chao (1968), however, little attention was paid to this sector of the Chinese economy until Parker (1994a), who recently used a generalized restricted cost function to compare state-owned construction enterprises to urban collectives from 1985 to 1988. This present study extends that data set to 1991 for state-owned enterprises in order to cover the full period until the announcement of the Socialist Market Economy. It also estimates a different generalized cost function, one that estimates the shadow price ratio for capital. Most importantly, this present study shows how convergence can be estimated in this context as a measure of the response to economic reform.

The results do not present consistent evidence for improved efficiency as a response to reform by Chinese state-owned construction enterprises during the study period, and these results are consistent with the troubles of the state enterprise. While multifactor productivity did show some improvement, especially during the latter half of the 1980’s, only labor’s relative price efficiency appeared to improve over time. Bidding reforms did improve measured price efficiency, but the contracted responsibility system worsened it. The dispersion of price inefficiency increased over time, implying that observation-specific factors played an even stronger role in enterprise behavior, and reform did not adequately counteract this tendency.

2. A MODEL OF ENTERPRISE INEFFICIENCY

Convergence may be defined as a measured movement of economic choices toward efficient levels. One aspect of improved efficiency is price equaliza-

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Footnote: Announced at the 14th National Congress of the Chinese Communist Party, this signaled a major shift in government policy toward the economy. A major component of the Shehuitzhui Shichang Jingji is the reform of state enterprise management, up to and including the partial or even full privatization of ownership.
tion; the pure theory of international trade, for example, argues that the lowering of trade barriers is efficient policy because it tends to make both output and factor prices more equal across countries. As a result of international trade and foreign investment, reduced provincial-level autarky, two-tier pricing, and gradual price reform, it is perhaps possible that prices in China may one day reflect true scarcity values. However, economic reform must not only get prices right, it must also ensure that enterprises respond appropriately to those prices.

To model enterprise decision making, assume that all Chinese state-owned construction enterprises face identical linearly homogeneous production technologies,

\[ Q = \phi(V). \]  

Output \( Q \) is assumed to be a function of an \( n \)-dimensional vector of observed inputs, \( V \), where \( V \) contains material inputs, labor, and productive fixed assets. If the firm is efficient in choosing the cost-minimizing level and mix of inputs, then

\[ W^*_i = \mu \phi_i = P_i \forall i, \quad \text{where} \quad \phi_i = \frac{\partial \phi}{\partial V_i}, \]  

and \( \mu \) is marginal cost while \( P_i \) is the input’s shadow price. The ratio of the input’s true shadow price to its true factor price is defined as the true shadow price ratio \( \xi^*_i \). If the firm produces the efficient level of output, such that marginal cost equals output price \( P_Q \), then this condition may be rewritten as equating the true shadow price ratio to unity,

\[ \frac{\mu \phi_i}{W^*_i} = \frac{P_i}{W^*_i} = \xi^*_i = \frac{P_i \phi_i}{W^*_i} = 1 \quad \forall i. \]  

The socialist enterprise may not appear to meet these conditions for several reasons. First, economic variables may be mismeasured, particularly with regard to the measurement of prices. Second, it is expected that factor markets may not clear in a state-managed economy. Third, and most important, is the improbability that the state-owned enterprise minimizes costs or maximizes profits. These issues are discussed below.

*Price Measurement Errors*

Reported or estimated factor prices do not necessarily reflect the true prices being paid by the enterprise. Wages for labor do not reflect all of the benefits-in-kind which, according to Lardy (1983), may almost double the true wages for state employees with the so-called iron rice bowl. Prices for capital may be mismeasured or not reflect the implicit subsidy inherent in state investment
allocations or loans with no expectation of collection. Let us assume that the true price for each input equals a firm-specific measurement error ratio \( k_i \) times the observed factor price \( W_i \), so
\[
W^*_i = k_i W_i \quad \forall i.
\] (4)

Even if the enterprise is choosing its inputs efficiently, such that \( \xi^*_i = 1 \) for all \( i \), it will not appear to be doing so unless \( k_i = 1 \).

**Shortages**

In China, many factors of production are still controlled by the center, and when prices are controlled, shortages often result. For example, producers of Portland cement, one of the primary inputs into the construction sector (the other two primary inputs are steel and timber), paid rising input costs throughout the mid-1980’s without adjustment in their official output price, severely dampening “producer enthusiasm” (Jingji Ribao, 1985) and leading to scarce supplies. Even if the enterprise prefers to use an input efficiently, the enterprise will appear to be inefficient if the input is unavailable.

**Motive Errors**

Because the enterprise decision maker may have concerns other than profit maximization given a set of exogenous prices, the enterprise may not choose the profit-maximizing amounts of its inputs and output. These other motives might include output maximization for plan fulfillment, average profit maximization to please workers by the size of their bonuses, factor level maximization to maximize employment or capitalization or to hoard scarce inputs, or maximization of benefits correlated with inefficient management.\(^5\)

To illustrate this further, I introduce below a generalized static model of the enterprise’s objective function that allows for a few different sources of inefficiency. Maximization of a utility function that contains other motives in addition to maximizing profit will result in the measurement of apparent inefficiency, even if that choice is efficient from the point of view of the decision maker. The observation of apparent inefficiency is made even more likely by the presence of input constraints common in the state socialist economy and by the likelihood that the input prices observed by the economist may deviate significantly from the prices actually paid by the enterprise. In the face of this myriad of reasons for inefficiency, the assumption that eco-

\(^5\) Kornai (1980) argues that the socialist firm faces a soft budget constraint and that this leads to investment hunger and an expansion drive without regard to the marginal products of labor, capital, and other inputs. For a survey of the theory of the socialist enterprise, see Kornai (1992).
nomic reform will cause enterprises to become measurably more efficient in input usage is suspect.

A common complaint regarding socialist enterprises is that there are numerous decision makers. Local governments, the Party, various and competing government ministries, and even local neighborhood committees all contribute to complaints of "too many mothers-in-law" (Gutowski and Merklein, 1986). Prasnihar et al. (1990) suggest a model of the enterprise in the former Yugoslavian economy in which the decision making process is best described through a utility function combining the interests of labor, management, and government. Using this general approach, which allows for the specification of a utility function for a group of people, let us suppose that, in the socialist enterprise, the objective of the decision makers is the maximization of the following utility function, containing profits $\pi$ as well as vectors of both the $n$ average profits $\omega_i$ per unit of each input and the $n$ physical inputs $V_i$ themselves$^6$:

$$\text{MAX } U[\pi, \bar{\omega}, \bar{V}].$$

(5)

If Chinese state enterprises operated under the traditional central plan, output or other arguments might be included. The utility function is assumed to be quasiconcave with nonnegative marginal utilities. The relative magnitudes of these marginal utilities result from a process of negotiation between competing interests, and, therefore, they are assumed to be affected by changes in institutional arrangements.

For simplicity, it is assumed that the enterprise faces parametric prices for output, $P_o$, and the $n$ inputs, $W^*_i$. Profits are the residual of revenue, $P_oQ$, less the costs of $n$ observed inputs. As discussed above, input prices may differ from observed input prices, $W_i$, due to the presence of subsidies, side-payments, or nonmonetary payments known to the enterprise decision makers but unobserved by the econometrician. Furthermore, inputs may have a binding quantity constraint $V_i$. Utility is therefore maximized subject to the following conditions:

1. $\pi = \pi(\bar{V}) = P_oQ - \sum_{j=1}^{n} W_j^* V_j$

2. $Q = \phi(\bar{V})$

3. $\omega_i = \omega_i(\bar{V}) = \frac{\pi(\bar{V})}{V_i}$ \quad $\forall i$

$^6$ While this is intended to capture the motives of labor hoarding or, in contrast, maximizing profit per worker, the expression is generalized to all inputs.
\( (4) \quad V_i' - V_i = c_i' = 0 \quad \forall i. \)  

The utility function can be rewritten as an indirect function of the factors of production, the vector \( V \), and \( c_i \), the square root of slack for each input; maximizing utility over these choice variables, the following first-order conditions are derived:

\[
\text{MAX } U[\pi(\tilde{V}), \tilde{\omega}(\tilde{V}), \tilde{V}] + \sum_{j=1}^{n} \lambda_i (V_j' - V_j - c_j' = 0) \quad \forall i. 
\]

\[
dU_{\tilde{V}} = \frac{\partial U}{\partial \pi} (P_{\phi_i} - W_i^*) + \sum_{j=1}^{n} \frac{\partial U}{\partial \omega_i} \left( \frac{P_{\phi_j} - W_j^*}{V_j} \right) 
\]

\[
- \frac{\partial U}{\partial \omega_i} \left( \frac{\pi}{V_i} \right) + \frac{\partial U}{\partial V_i} - \lambda_i = 0 \quad \forall i; 
\]

\[
dU_{c_i} = -2\lambda_i (V_i' - V_j)^{1/2} = 0 \quad \forall i. \quad (7) 
\]

The parameter \( \lambda_i \) is the Kuhn–Tucker multiplier for each input quantity constraint; the last first-order condition implies that either \( V_i' \) is a binding constraint or the marginal value of slack, \( \lambda_i \), equals zero. Assuming again that \( W_i^* = k_i W_i \) and normalizing marginal utilities by dividing through by the marginal utility of profit, the first-order conditions can be solved to derive a solution to the observed shadow price ratio, the shadow price divided by the observed factor price,

\[
\xi_i = \left( \frac{\mu_{\phi_i}}{W_i} \right) = \frac{\mu k_i}{P_o} + \frac{\mu}{P_o W_i} \left( \frac{\omega_i \pi}{V_i^2} + \lambda_i - u_{i_t} \right) \left( 1 + \sum_{j=1}^{n} \frac{u_{i_j}}{V_j} \right). \quad (8) 
\]

In this expression, the observed shadow price ratio \( \xi_i \) equals the measurement error ratio \( k_i \) times the true shadow price ratio \( \xi_i^* \). This expression collapses to an expression identical with unity if \( k_i = 1 \), the marginal utility of reduced shortage \( \lambda_i = 0 \), the output price equals marginal cost, and the non-profit normalized marginal utilities \( u_a = 0 \ \forall a = [\omega_1, \omega_2, \omega_3, V_1, V_2, V_3] \). The enterprise will appear to be price inefficient if any of the \( \xi \) ratios vary from one, which can happen even if the true prices used by the enterprise in decision making match those observed by the experimenter. The observed input–price efficiency obviously depends on the relative size of marginal utilities, quantity constraints, and errors in measuring true prices.

**Implications for Convergence**

An economy that moves in the direction of market efficiency should show evidence of convergence. As markets move toward competitive efficiency,
prices converge toward each other, marginal costs converge toward market prices, and marginal revenue products converge toward factor prices. To the degree that past research on Chinese reform has considered convergence, it has tended to focus either on industries becoming more alike or on marginal rates of substitution converging toward factor price ratios. However, if profit-maximizing firms become more alike in their technologies and their input mixes, then the dispersion of inefficiency convergences toward zero. This convergence in dispersion should occur even if convergence of marginal revenue products toward factor prices does not.

Economic reform in socialist economies has been an attempt to change the institutional arrangements of decision making, to give managers more control over input decisions or to increase the marginal utility of profit, for example. If the socialist government’s economic reforms are successful in compressing the utility function to the profit function, increasing slack in input quantity constraints, and reporting input costs accurately, then a factor’s marginal revenue product should converge to its input price. If any of these conditions are not met, then economic reforms may cause an observed convergence toward a value other than unity. If the marginal utilities, shortages, or price errors continue to vary by enterprise, then convergence may not be observed at all, even if economic reforms have been fairly successful, because the mean of a given efficiency index may not have changed even as the dispersion of enterprise inefficiency fell.

Consider, instead, the variances of the $\xi_i$ ratios when $k_i = 1$ and $\lambda_i = 0 \forall i$. This model predicts zero variation for the profit-maximizing case, since all marginal utilities cancel out, so what variance exists results entirely from the estimation process. All other cases, however, generate $\xi_i$ ratios that contain parameters that may vary dramatically across enterprises, provinces, ministries, and time. Letting $R$ represent a vector of economic reform variables and $a$ the vector of normalized marginal utilities of nonprofit objectives, the impact of economic reform on the variances of the $\xi_i$ ratios can be expressed as

$$\frac{d \text{Var}(\xi_i)}{dR_j} = \sum_a \left( \frac{\partial \text{Var}(\xi_i)}{\partial u_a} \frac{\partial u_a}{\partial R_j} + \frac{\partial \text{Var}(\xi_i)}{\partial \lambda_i} \frac{\partial \lambda_i}{\partial R_j} + \frac{\partial \text{Var}(\xi_i)}{\partial k_i} \frac{\partial k_i}{\partial R_j} \right).$$  \hspace{1cm} (9)

If reforms succeed in decreasing the marginal utility of slack by reducing input shortages, or if price measurement errors are reduced, then the variance of the shadow price ratio will clearly fall. If reform succeeds in slightly reducing the preference for nonprofit objectives, then the effect on the shadow price ratio variance is not entirely clear because the denominator of the shadow price ratio may affect the size of the variance. The limit of the variance, however, as nonprofit marginal utilities go to zero, is also zero. On average, therefore, this variance should fall as a result of reform if the partials of the these normalized marginal utilities with respect to reform are negative.
Therefore, an important implication of this model is that changes in the dispersion of the $\xi$ ratios can represent changes in the degree to which objectives other than profit maximization are present. This variance cannot be directly separated from the variance resulting from the estimation process itself, but changes in this variance as a result of reform indicate the relative proportion of marginal utilities in the $\xi$ ratios.

Paying attention to the variance gives us additional information. Consider the case of continuing effective capital subsidization in the face of falling nonprofit marginal utilities. If the true prices observed by the enterprise deviate consistently from prices observed by the researcher, then mean allocative efficiency may not improve. A reduction in the random component of this deviation may still be observed, however, if enterprises are approaching the behavior of profit-maximizing firms in the face of these consistent price errors. Jefferson and Xu (1991), for example, suggest that this type of convergence in efficiency can be measured by decreases in the coefficient of variation, but if convergence can be thought of as a reduction in the variance, perhaps this can be looked for when evaluating the response to reform, and perhaps the significance of the response of the variance to reform variables can be tested.

This gives us an extra tool with which to test the impact of economic reform. To the extent that reforms have been able to emphasize profit maximization over other objectives, there should not only be improvements in overall efficiency, both technical and allocative, but also a reduction in the observed variance. Like unhappy families, inefficient firms are each inefficient in their own way; as state enterprises act more like efficient firms, they become more alike in their use of resources.

3. CHINESE STATE-OWNED CONSTRUCTION ENTERPRISE DATA

In developing countries, the construction sector usually accounts for one-half to two-thirds of capital formation (Cockburn, 1970, p. 7; Rau, 1983), and it is also the primary transitional employer as an economy industrializes. After China's opening to the West, real net output in construction grew at an annual rate of 10.7% between 1978 and 1984. In the eight years following what has been called the second wave of economic reform and the start of real urban reform,7 from 1984 to 1992, real net output growth in construction accelerated slightly to 11.1% in spite of two recessions. Most of this growth, however, was outside of the directly state-managed sector, in urban collectives and rural enterprises.

The construction sector was one of the first sectors of the Chinese economy

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7 Beginning after the "Decision of the Central Committee on Reform of the Economic Structure" in October 1984, these reforms began to change state enterprise incentives in earnest (Zhongguo Jingji Tizhi Gaige, 1990; Riskin, 1991, p. 342).
to undergo socialist transformation in the early 1950’s (Chao, 1968), and
following the introduction of urban economic reforms in 1984 it ‘. . . was the
first industry to carry out overall reform’ (Zhan, 1986). Economic reforms,
mirroring those implemented throughout industry, have attempted to substitute
taxes for profit remittances, to reduce the free good aspect of investment
allocations, and to give local authorities and managers more control over
production decisions. In construction, a system of allocating a share of con-
struction projects on the basis of competitive bidding has been implemented
in order to shorten time limits, reduce costs, and improve quality (Jiang,
1985). The Chinese press complained, however, that competitive bidding had
mixed results at best (Zhu, 1986).

The provincial-level data used in this research to evaluate the response to
economic reforms by the state-owned construction sector was collected for
seven years (1985–1991) from the Chinese statistical yearbooks (CSSB,
Zhongguo Tongji Nianjian) and biannual construction statistics (CSSB,
Zhongguo Jianzhuye Tongji Ziliao). In 1991, construction enterprises ac-
counted for 63% of total construction output, with the rest produced by
internal units of nonconstruction enterprises. Of the 228 billion yuan (Ren-
mindi) produced by dedicated construction enterprises, almost a third was
produced by state-owned enterprises under provincial authority; the rest was
produced by rural construction teams, urban collectives, and state-owned
enterprises under ministerial authority, and the available data for these enter-
prises is not complete. Data is available for 30 administrative divisions (three
municipalities, five so-called autonomous regions, and 22 provinces, including
Hainan Island after 1988). There are 206 observations in all.

At least for aggregated state-owned construction enterprises under the au-
thority of the provincial authorities, these sources contain data of reasonable
consistency, completeness, and quality. In a systematic review of Chinese
statistics, Taylor and Banister (1989) noted that Chinese statisticians were
‘eager to gather objective information, even if the figures they collect and
calculate are politically worrisome, and they express their determination to
tell it like it is to the leadership’ (p. 56). They conclude that there is not a
separate set of books for the leadership. National accounts and other data are
consistent, if subject to change, while accounting for price changes is poorly
understood. The problems that do emerge from data collected to ‘moni-
tor, audit, judge, or even reprimand the respondents.’

The data collected includes both gross and net output values, both original
and net value of fixed assets, the net value of equipment, the average number
of staff and workers, the electrical capacity of equipment per worker, profit
rates, total wages (including contributions to welfare funds), output and material
price indices, the percentage of floorspace under construction by enterprises
that engaged in bidding for the job, and the percentage of floorspace under
construction that fall under some form of contracted responsibility system.
Output and materials price indices are calculated from available provincial and ministry-level inflation data, with 1984 as the base year. The output and material price indices account for inflation within a given province, but not for price differences across provinces. Since output quality may differ from province to province, any interprovincial price index adjustment based on physical quantities of output, such as floorspace, would fail to correct for differences in product. Though a two-tier pricing structure is common in postreform China, it is assumed that marginal and average prices are equal, since the state, either directly or through other state-owned enterprises, is still the primary purchaser of output for state-owned construction enterprises.

Output \( Q \) is defined as the gross value of output deflated by the provincial price index \( P_Q \). Material inputs, \( V_m \) or \( V_3 \), are assumed to be the simple difference between gross and net output value as adjusted by the materials price index, \( P_m \) or \( P_3 \). Labor inputs, \( V_l \) or \( V_2 \), are proxied by the average number of staff and workers. The average price of labor, \( P_l \) or \( P_2 \), includes base wages, piece-rate payments, overtime, above-quota payments, bonuses, and payments to welfare funds, but not other indirect subsidies and benefits-in-kind. All data is expressed in per-enterprise terms. To proxy for patterns of economic reform, I use \( B \), the provincial average percentage of floorspace under contracts obtained by competitive bidding; \( C \), the provincial average percentage of floorspace under contracted responsibility systems; and \( T \), which is zero in 1985 and rises by one annually, as a proxy for other reforms coming online between 1985 and 1991.

To estimate capital stock, \( V_k \) or \( V_1 \), an annual deflator for capital is derived to account for the changing value of annual gross investment, less scrap and depreciation, based on methods used by Chen et al. (1988a), Jefferson et al. (1992), and Parker (1992). Inflation in incremental investment is proxied by a gross output deflator from the machine-building industry. Ideally, this deflator would be applied to the net value of productive fixed assets, since a significant portion of total fixed assets contains nonproductive investment that reflects the paternalistic role of the Chinese enterprise more than it reflects any concern with productivity measures. However, since the ratio of productive investment is unavailable at the ministry level, the net value of equipment divided by the above deflator is used instead as a proxy for capital. Following Moroney and Trapani (1981), the return to capital, \( P_k \) or \( P_1 \), is assumed to be the residual of value-added less profit and labor cost divided by the adjusted capital stock, so that the nominal value of output equals cost plus profit.

4. THE ESTIMATION OF CONVERGENCE

Convergence implies movement of the shadow factor price ratio (the ratio of a factor’s marginal revenue product to its price) toward unity, and/or movement of its variance towards zero. However, the shadow price ratio is
not directly observed; it must first be estimated. In this section, I first specify a generalized cost-function model that will allow the estimation of input price inefficiency and shadow price ratios, in order to determine whether the marginal rates of technical substitution have converged toward the factor price ratios. Second, I derive equations for the variance of the shadow price ratios and test whether or not the shadow price variances have converged even if the ratios have not.

*Estimating a Generalized Cost Function*

The generalized cost function methodology is a well-developed methodology for estimating price inefficiency as defined by Farrell (1957). This method was developed in the profit function context by Lau and Yotopoulos (1971), Yotopoulos and Lau (1973), Atkinson and Halvorsen (1980), and Lovell and Sickles (1983), and extended to a cost function context by Toda (1976) and Atkinson and Halvorsen (1984). Most studies of the Chinese economy have relied on Cobb–Douglas production functions, and of these only Murakami et al. (1994) estimated price inefficiency. Parker (1994c) has shown that the generalized cost function provides significantly better estimates of price inefficiency than the production function, and that it also provides better estimates of the underlying technology when price inefficiency is present.

Assume that the decision makers minimize a well-defined but unobserved shadow cost function subject to unobserved shadow input prices. In the context of a Chinese state-owned enterprise with the behavioral constraints described above, the enterprise is assumed to be maximizing utility subject to fixed output, input shortages, and nonprofit objectives. In comparing state-owned construction enterprises to urban collectives, Parker (1994a) estimated a restricted generalized cost function that assumed that capital was fixed. Here I assume instead that all inputs, capital, labor, and materials, are variable. The shadow input price is first defined as

\[
P_i = \xi_i^* W_i^* = \mu \phi_i = \left( \frac{\mu \phi_i}{W_i} \right) W_i = \xi_i W_i \quad \forall i.
\]

The shadow cost function \( C^f \) is assumed to be a function of shadow prices \( P_K, P_L, \) and \( P_M \), numbered \( P_1, P_2, \) and \( P_3 \); also included as arguments are real output \( Q \) and reform variables \( R = \{ T \) (time), \( B \) (bidding system), \( C \) (contracted responsibility system)\}, numbered \( R_1, R_2, \) and \( R_3 \). This cost function is initially specified as a flexible translog functional form,

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* See, for example, Jefferson (1989), Dollar (1990), Lee (1990), Xiao (1991), and Jefferson et al. (1992).
\[ \ln C^5 = A_0 + \ln Q + \sum_{k=1}^{3} \alpha_k \ln P_k + \frac{1}{2} \sum_{k=1}^{3} \sum_{j=1}^{3} \beta_{kj} \ln P_k \ln P_j \\
+ \sum_{r=1}^{3} \gamma_r R_r + \frac{1}{2} \sum_{r=1}^{3} \sum_{s=1}^{3} \gamma_{rs} R_r R_s + \sum_{k=1}^{3} \sum_{r=1}^{3} \theta_{kr} \ln P_k R_r. \] (11)

Due to the use of aggregated provincial-level data, the underlying technology is assumed to exhibit constant returns to scale. Since cost functions must be linearly homogeneous and concave in factor prices, the following restrictions are imposed:

\[ \sum_{k=1}^{3} \alpha_k = 1; \quad \sum_{k=1}^{3} \beta_{kj} = 0 \quad \forall j; \quad \sum_{k=1}^{3} \theta_{kr} = 0 \quad \forall r. \] (12)

Concavity of prices in the translog cost function cannot be costlessly imposed (Diewurt and Wales, 1987), but it can be tested after estimation using parameter means for each observation. By Young's Theorem, symmetry is imposed on the \( \beta_{kj}, \gamma_{rs}, \) and \( \theta_{kr} \) parameters. The parameter \( A_0 \) is assumed to embody fixed effects resulting from provincial differences in average quality or initial average price of housing, so that it is specified as a function of dummy variables \( D_p \),

\[ A_0 = \delta_0 + \sum_{p=2}^{30} \delta_p D_p. \] (13)

By Shephard's Lemma, the shadow share of the \( i \)th input is the first partial derivative of \( \ln C^5 \) with respect to \( \ln P_i \),

\[ S_i^5 = \frac{P_i V_i}{C^5} = \frac{\partial}{\partial \ln P_i} \ln C^5 = \alpha_i + \sum_{k=1}^{3} \beta_{ki} \ln P_k + \sum_{k=1}^{3} \theta_{ki} R_k, \] (14)

where \( V_i \) is the level of the \( i \)th input. This cost function cannot be directly estimated, however, since neither shadow price nor shadow cost is directly observed. Instead, input prices \( W_i \) are observed, and it is assumed that \( \xi_i \), the ratio of shadow price to observed price, is an estimable function of other variables. Because of linear homogeneity in prices, only relative price inefficiency can be estimated; therefore \( \xi_M \) is arbitrarily set to unity, and both \( \xi_k \) and \( \xi_r \) are relative shadow price ratios, relative to \( \xi_M \). These two remaining shadow price ratios are assumed to be exponential functions of reform variables. In addition, a dummy variable \( I \) is included to test the hypothesis that Chinese coastal provinces are more price efficient than interior provinces due to the increasing presence of foreign investment.° These shadow price ratios are:

° Interior provinces are assumed to include Inner Mongolia, Jiangxi, Henan, Hubei, Hunan, Guangxi, Sichuan, Guizhou, Yunnan, Xizang (Tibet), Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.
\[
\ln \xi_i = \xi_{i0} + \sum_{r=1}^{3} \xi_{ir} R_r + \xi_{id}.
\] (15)

The observed (nonminimum) cost function \(C\) is a function of the shadow (minimum) cost function and the shadow shares, such that
\[
\ln C = \ln C^s + \ln \left( \sum_{i=1}^{3} \frac{S_i^s}{\xi_i} \right),
\] (16)

and the resulting observed share equations \(S_i\) are
\[
S_i = \frac{W_i V_i}{C} = \frac{S_i^s}{\xi_i} \left( \sum_{i=1}^{3} \frac{S_i^s}{\xi_i} \right)^{-1}.
\] (17)

Because the three observed shares sum to unity by definition, the last share equation \(S_M\) is dropped.\(^{10}\) The resulting system of one cost function in log form and two share equations can be simultaneously estimated using nonlinear methods that approximate the iterative Zellner Seemingly Unrelated Regressions (SUR) method, and the results can be used to test hypotheses of price inefficiency and convergence in response to reform.

**Estimating Shadow Price Variances**

If the relative shadow price ratios estimated in the generalized cost function above do not show significant convergence towards unity, this suggests that perhaps price efficiency has not improved as a result of reform. For a socialist enterprise with numerous objectives and constraints as well as possible price mismeasurement, however, reform may not cause convergence of marginal revenue toward observed factor price even if the reform has been effective. Jefferson *et al.* (1992) suggest that improved efficiency in the mix of inputs is measurable by a reduction in the variance of estimated marginal rates of substitution within a sample or between samples. Convergence of the variance of the relative shadow price ratio towards zero may in fact be better evidence that reform has improved the profit objective even if it has not solved all problems.

Since the relative shadow price ratios are parametrically estimated, their variances must be indirectly calculated if they are to be meaningful. Following Klein (1953, p. 258), a Taylor series second-order approximation of the variance of a complex function \(f(X)\), where \(X\) is a vector of variables, is
\[
\text{Var}(f(X)) \approx \sum_{i=1}^{n} \sum_{j=1}^{n} \text{Cov}(X_i, X_j) \left( \frac{\partial f(X)}{\partial x_i} \right) \left( \frac{\partial f(X)}{\partial x_j} \right).
\] (18)

\(^{10}\) According to Greene (1980), the results are invariant to the share equation dropped.
Assuming that the variances of observed cost and observed shares are a function of estimated shadow cost, shadow shares, and shadow price ratios, and that the covariances between these elements are zero, the variance of the observed cost function can be solved,

$$\text{Var}(\hat{C}) \approx \text{Var}(\hat{C}^E) \left( \frac{\hat{C}}{\hat{C}^E} \right)^2 + \sum_{i=1}^{n} \left[ \text{Var}(\hat{S}^E_i) \left( \frac{\hat{S}^E_i}{\xi_i} \right)^2 + \text{Var}(\hat{\xi}_i) \left( \frac{-\hat{C}^E \hat{S}^E_i}{\xi_i} \right)^2 \right].$$

(19)

Assuming that only the variances of the two relative shadow price ratios are unknown, this can be rearranged to form an equation at the observational level. All estimates other than the shadow price variance are assumed for simplicity to be known observational-level variables, where $e$ is the subscript for the observation,

$$\left[ (\hat{C}_e - \text{avg}(\hat{C}))^2 - (\hat{C}^E_e - \text{avg}(\hat{C}^E))^2 \left( \frac{\hat{C}_e}{\hat{C}^E_e} \right)^2 - \sum_{i=1}^{n} (\hat{S}^E_i - \text{avg}(\hat{S}^E))^2 \left( \frac{\hat{S}^E_i}{\xi_i} \right)^2 \right]$$

$$= \sum_{i=1}^{2} \text{Var}(\hat{\xi}_i) \left( \frac{\hat{C}^E \hat{S}^E_i}{\xi_i} \right)^2 + \epsilon_e.$$  

(20)

Since the two relative shadow price ratios also enter the observed share equations, these equations are also used to derive estimates of their variances,

$$\text{Var}(\hat{S}_i) \approx \text{Var}(\hat{S}^E_i) \left( \frac{\hat{S}^E_i}{\hat{\xi}_i} \right)^2 + \text{Var}(\hat{\xi}_i) \left( \frac{-\hat{C}^E \hat{S}^E_i}{\hat{\xi}_i} \right)^2$$

$$+ \sum_{k=1}^{3} \left[ \text{Var}(\hat{S}^E_k) \left( \frac{\hat{S}^E_k}{\hat{C}} \right)^4 \left( \frac{-\hat{S}^E_i}{\hat{\xi}_i \hat{\xi}_k} \right)^2 + \text{Var}(\hat{\xi}_k) \left( \frac{\hat{C}^E \hat{S}^E_k}{\hat{\xi}_k} \right)^4 \left( \frac{\hat{S}^E_i \hat{S}^E_k}{\hat{\xi}_i \hat{\xi}_k} \right)^2 \right].$$  

(21)

These estimating equations, which can be estimated for all three inputs at the observational level, are rearranged and specified as

$$\left[ (\hat{S}_e - \text{avg}(\hat{S}_i))^2 - (\hat{S}^E_e - \text{avg}(\hat{S}^E))^2 \left( \frac{\hat{S}_e}{\hat{S}^E_e} \right)^2 \right]$$

$$- \sum_{i=1}^{n} (\hat{S}^E_i - \text{avg}(\hat{S}^E))^2 \left( \frac{\hat{S}^E_i}{\hat{\xi}_i} \right)^2 \right] = \text{Var}(\hat{\xi}_e) \left( \frac{-\hat{C}^E \hat{S}^E_i}{\hat{\xi}_e} \right)^2$$

$$+ \sum_{i=1}^{2} \text{Var}(\hat{\xi}_i) \left( \frac{\hat{C}^E \hat{S}^E_i}{\hat{\xi}_i} \right)^4 \left( \frac{\hat{S}^E_i \hat{S}^E_k}{\hat{\xi}_i \hat{\xi}_k} \right)^2 + \epsilon_e.$$  

(22)
There are now four simultaneous equations to estimate the two relative shadow price ratio variances, and these can be specified as a linear function of reform variables,

$$\text{Var}(\xi_i) = \nu_0 + \sum_{r=1}^{3} \nu_r R_r, \quad \forall i = K, L.$$  \hspace{1cm} (23)

5. RESULTS OF THE ESTIMATION

In this section, the hypotheses of the convergence model are tested using the generalized cost function method and variance equations described above. The generalized cost function model consists of the observed translog cost function in Eq. (16), estimated simultaneously with the observed share equations in Eq. (17) for capital (K) and labor (L). It is necessary to substitute in for the shadow cost function in Eq. (11), the shadow shares in Eq. (14), the provincial intercept in Eq. (13), the shadow price in Eqs. (10) and (15), and the restrictions in (12). Estimation of this nonlinear system was obtained through a quasi-Newton method which approximates maximum likelihood.\(^{11}\)

**Generalized Cost Function Results**

For purposes of comparison, Table 1 displays estimates and standard errors for three versions of this econometric model. The first version is the unrestricted model, as described above. The second version imposes factor price efficiency by setting the $\xi$ parameters to zero, thereby linearizing the system of equations and making estimation by the iterative SUR method possible. The third version removes bidding and contract responsibility reform variables in order to more clearly identify the general trend of changes over time. Estimated parameters reported include core cost function parameters, shadow price parameters, and dummy variable parameters. It can be shown by taking the natural exponent of the dummy variable parameter estimates that, relative to province 1 (Beijing), there are significant differences in 1984 average costs; these range from 9% below in Shanghai, province 9, to 24% above in Fujian, province 13. In general, dummy parameter estimates are consistent across the three versions.

\(^{11}\) The estimation method is an alternative Davidson–Fletcher–Powell algorithm available under SHAZAM that minimizes the determinant of the summed equation covariance matrix. The correction and covariance matrices are estimated analytically, rather than numerically, since numerical methods yield Hessians that are extremely susceptible to step sizes. Before calculating logarithms, prices and total cost are normalized to a mean of one, and quantities are adjusted appropriately in order to leave the economic relationships intact. Estimation was attempted with a variety of starting points and methods to increase the likelihood of finding the global minimum, and the parameter estimates were remarkably stable.
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<th>Trend model</th>
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</table>

**In \( \ell \)\:**

- 1602.57       | 1522.31       | 1581.86

*** Significant at 2.5% (one-tailed or 5% (two-tailed).

** Significant at 5% (one-tailed) or 10% (two-tailed).

* Significant at 10% (one-tailed) or 20% (two-tailed).
Relative to the unrestricted model, both the linear model and the trend model can be rejected with at least 5% significance, based both on likelihood ratio tests and Wald tests. However, in the unrestricted model there are a number of core cost-function parameters that are not significant at the 5% (two-tailed) level, perhaps due to some degree of quasimulticollinearity in the nonlinear translog of the generalized cost function. A Wald test for joint insignificance of the second-order terms, the $\beta$, $\gamma$, and $\theta$ parameters, which would impose the hypothesis that the cost function is of Cobb–Douglas form, is rejected at 5% significance. Similarly, the individual hypotheses that time, bidding, and/or the contract responsibility system can be excluded from the cost function are rejected.

Most importantly, the hypothesis of relative factor–price efficiency is strongly rejected in the unrestricted model. This is shown in the strong rejection of the linear model above, as well as for both capital and labor individually, each, of course, relative to materials. The Wald $\chi^2$ test statistic for the combined hypothesis is 232.3, with ten degrees of freedom; the likelihood ratio test statistic is 160.5. For relative capital price efficiency, this statistic is 62.2 with five degrees of freedom, and for labor it equals 161.9. All logical subgroupings of price efficiency hypotheses are rejected in the unrestricted model. In fact, the only circumstance in which a relative price efficiency hypothesis is not rejected at 5% significance is in the trend model; in this version, only the hypothesis of relative capital price efficiency for coastal provinces cannot be rejected.

Shadow price ratios for both capital and labor are low relative to material inputs, implying that both capital and labor are used in excess of their observed cost-minimizing amounts, assuming that materials are not extremely underused; this inefficiency is worse for the interior provinces. The hypothesis that interior provinces are equal in price inefficiency to coastal provinces is rejected at 5% significance. Bidding reforms are significantly correlated with an improvement in price efficiency for both factors, while the contracted responsibility system is significantly correlated with worsening price efficiency, and the time trend is significantly associated with an increased use of capital.

While the restricted trend model is strongly rejected with a Wald $\chi^2$ test statistic of 72.1 and 15 degrees of freedom (the likelihood ratio statistic is 41.4), it does show that the net effect of time and reform is an improvement in technical efficiency in the first part of reform, as average cost falls by approximately 1% per year. However, this trend slows by the end of the

---

12 The standard errors are still somewhat dependent on method and convergence criteria, even with an analytically-derived covariance matrix. The results shown are among the most consistent. Furthermore, it is not uncommon for estimates of translog-form shadow cost functions to yield individually insignificant parameter estimates.
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<td>-0.039</td>
<td>-0.120</td>
</tr>
<tr>
<td>$M_{KL}$</td>
<td>0.199</td>
<td>0.182</td>
<td>0.359</td>
</tr>
<tr>
<td>$M_{LM}$</td>
<td>0.350</td>
<td>0.319</td>
<td>0.487</td>
</tr>
<tr>
<td>$M_{LK}$</td>
<td>0.396</td>
<td>0.423</td>
<td>0.495</td>
</tr>
<tr>
<td>$M_{LM}$</td>
<td>0.574</td>
<td>0.610</td>
<td>0.633</td>
</tr>
<tr>
<td>$M_{MK}$</td>
<td>0.529</td>
<td>0.507</td>
<td>0.626</td>
</tr>
<tr>
<td>$M_{MR}$</td>
<td>0.725</td>
<td>0.747</td>
<td>0.761</td>
</tr>
<tr>
<td>Concavity</td>
<td>86.2%</td>
<td>89.7%</td>
<td>96.7%</td>
</tr>
<tr>
<td>Monotonicity</td>
<td>100.0%</td>
<td>100.0%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

sample period. The price efficiency of labor also improved, as the effect of time on labor’s shadow price ratio is significantly positive, but the net effect of time on the shadow price ratio for capital was insignificantly negative, implying that the overuse of capital did not ameliorate throughout the 1980’s.

**Descriptive Statistics of the Generalized Cost Function**

In Table 2, descriptive statistics of the estimation are shown for three years, 1985, 1988, and 1991, to show how construction’s efficiency changed over time. These statistics are calculated for each observation and reported at their mean. These statistics include observed cost shares as well as estimated shadow shares, estimated shadow factor price ratios, and the percentage of
Observations which meet requirements for concavity and monotonicity in shadow prices. Also included are indices of technical, price, and production efficiency, as well as elasticities of substitution between factors and net derivatives of the cost function with respect to reform variables.

The index of technical efficiency requires calculation of the generalized cost function absent the estimated effect of reform variables. Using estimated parameters, a measure of cost is calculated which leaves out the effect of R variables by setting all \( \tau, \gamma, \) and \( \theta \) parameters to zero,

\[
\ln \hat{C} = \hat{\delta}_0 + \sum_{p=2}^{30} \hat{\delta}_p \delta_{p} + \ln Q + \sum_{i=1}^{3} \hat{\alpha}_i \ln \hat{P}_i + \frac{1}{2} \sum_{i=1}^{3} \sum_{j=1}^{3} \hat{\beta}_{ij} \ln \hat{P}_i \ln \hat{P}_j + \ln \left[ \sum_{i=1}^{3} \left( \hat{\alpha}_i + \sum_{j=1}^{3} \hat{\beta}_{ij} \ln \hat{P}_j \right) / \hat{\xi}_i \right].
\] (24)

The index of technical efficiency, normalized so that the maximum observed efficiency is unity, may then be calculated as

\[
\eta_T = \frac{\hat{C}}{C} \left( \max \left\{ \frac{\hat{C}}{C} \right\} \right)^{-1}.
\] (25)

It is important to note that interprovincial differences in this index are not meaningful or even expected, since the dummy variables already account for average cost differences; however, changes over time should reflect the changes in average cost due to the effects of reform. For short-run price inefficiency, the appropriate index is the ratio of shadow to actual costs, once relative technical inefficiency is separated out. This index is unity if \( \xi_i = 1 \ \forall i \).

\[
\eta_P = \frac{\hat{C}^S}{C}.
\] (26)

Finally, an aggregate short-run efficiency index, \( \eta \), is derived that is the product of both technical and price efficiency,

\[
\eta = \eta_T \eta_P.
\] (27)

This aggregate index is perhaps the most useful, since the price efficiency index accounts for only relative price inefficiency. If all three of the shadow price ratios differ from unity, the cost function's linear homogeneity makes price inefficiency indistinguishable from technical inefficiency.

Consistent with the results described above for Table 1, the shadow price ratios for both capital and labor are low relative to that for materials, and while this improved slightly for labor inputs, it worsened for capital inputs. Shadow shares were relatively constant over time, but capital's observed share increased even as average profits decreased from 5.7% in 1985 to 3.5%
in 1988 and 1.8% in 1991. Overall price efficiency did not improve over the period of this study, while the mean net technical efficiency, including the effects of time and reform, improved by only 5.2% in six years, or less than 1% per year. Concavity and monotonicity conditions are checked using parameter estimates for each observation. Cost in all provinces for all years is monotonically increasing in factor inputs. Concavity is violated in 8% of the sample observations, but almost 14% of the observations violate concavity in 1985, and this falls to 3% by 1991.

In order to determine the underlying characteristics of the technology, Morishima elasticities of substitution are calculated; according to Blackorby and Russell (1989), these elasticities are better estimates of the true elasticities of substitution. For the translog shadow cost function, these simplify to

\[
M_{ij} = 1 + \frac{\hat{\beta}_{ij}}{\hat{S}_{ij}} - \frac{\hat{\beta}_{ij}^*}{\hat{S}_{ij}^*}, \quad (28)
\]

Even as violations of concavity decrease, substitution possibilities are increasingly elastic. The Morishima elasticities all increase over time, implying that the underlying production technology did become more flexible under reform and that technologies that allowed for substitution between factors increasingly did become available. At the mean, however, these elasticities are still inelastic relative to a Cobb–Douglas technology. As the elasticities of substitution increase, the costs of price inefficiency lessen.

The net effect of time and reform variables on multifactor productivity can be identified by the change in the technical efficiency index over time, but the net effect of each individual reform is difficult to identify since many parameters are involved. The response of average cost to time change alone is calculated as

\[
g_T = \left( \frac{\partial C^S}{\partial T} \right) \left( \frac{C^S}{C^S} \right) = \frac{\partial \ln C^S}{\partial T} = \bar{r}_T + \sum_{k=1}^{3} \hat{\alpha}_{kT} \ln \bar{P}_k + \sum_{s=1}^{3} \hat{\gamma}_s \bar{R}_s, \quad (29)
\]

and the effect of the other two reform variables can be calculated in elasticity form

\[
h_{R} = \frac{\partial \ln C^S}{\partial R} \frac{dR}{d \ln R} = R_T( \bar{r}_T + \sum_{k=1}^{3} \hat{\alpha}_{kT} \ln \bar{P}_k + \sum_{s=1}^{3} \hat{\gamma}_s \bar{R}_s). \quad (30)
\]

While the net effect of these reform variables has been to slightly improve technical efficiency over time, these derivatives show that neither the bidding reform nor the contracted responsibility system had a consistent effect on production costs. Bidding had a net cost-saving effect in 1985, but the respon-
### TABLE 3

**Variance Convergence Estimates**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unrestricted model</th>
<th>Trend model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate</td>
<td>Standard error</td>
</tr>
<tr>
<td>$\nu_{K1}$</td>
<td>0.0192</td>
<td>(0.0083)**</td>
</tr>
<tr>
<td>$\nu_{K2}$</td>
<td>0.0015</td>
<td>(0.0005)**</td>
</tr>
<tr>
<td>$\nu_{K3}$</td>
<td>0.0139</td>
<td>(0.0041)**</td>
</tr>
<tr>
<td>$\nu_{K4}$</td>
<td>-0.0303</td>
<td>(0.0081)**</td>
</tr>
<tr>
<td>$\nu_{L0}$</td>
<td>-0.0012</td>
<td>(0.0008)*</td>
</tr>
<tr>
<td>$\nu_{L1}$</td>
<td>0.0002</td>
<td>(4.84 × 10^{-4})***</td>
</tr>
<tr>
<td>$\nu_{L2}$</td>
<td>-0.0022</td>
<td>(0.0008)***</td>
</tr>
<tr>
<td>$\nu_{L3}$</td>
<td>3.36 × 10^{-4}</td>
<td>(0.0009)</td>
</tr>
<tr>
<td>ln $t$</td>
<td>3474.08</td>
<td></td>
</tr>
<tr>
<td>Sys. $R^2$</td>
<td>0.4037</td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

* Significant at 10% (one-tailed) or 20% (two-tailed).

**Notes:**

*** Significant at 2.5% (one-tailed) or 5% (two-tailed).

The table shows the estimates of the shadow factor price ratio variances, as given by the estimating equations described in Eqs. (20) and (22), substituting in Eq. (23) for the variance. These equations are linear in the shadow price variances, and four equations are simultaneously estimated, each with a constant term that is not reported. Since the errors are assumed to be correlated across equations, the iterative SUR estimation method is used. Using the estimates from the unrestricted generalized cost function in column 1 of Table I, two separate systems are estimated; the first is another unrestricted model in which the shadow price variances are specified as a function of all reform variables, the second is a trend model in which only change in the variance over time is estimated.

Bidding reform was significantly correlated with a decrease in labor’s shadow price ratio variance but an increase in that of capital. The responsibility system was significant in decreasing the variance of capital’s shadow price ratio, but had an insignificant effect on labor. Judging from the trend model, the variance of the shadow price ratio increased over time for both capital and labor, and neither reform was able to offset this general trend. The estimated dispersion of factor price inefficiency has not decreased, and state-owned enterprises across provinces have become less, not more, alike.
6. CONCLUSION

Economic reform during the period between China's two major policy shifts in 1984 and 1992 was very successful for the state-owned enterprise, according to a number of recent studies. If this were in fact true, then there should be evidence in official production statistics that state enterprises improved their price efficiency, that they not only were able to produce a greater value of output but also that they made some significant attempt to reduce the costs of that production. Shadow prices should have exhibited convergence toward factor prices, and even if reforms were only partly successful, the variance of the shadow price ratio should have significantly diminished across observations as enterprises became more alike in their use of inputs.

This paper has applied the generalized cost function method to annual provincial-level data from 1985 to 1991 for Chinese state-owned construction enterprises in order to test whether convergence has happened in the shadow price ratio. Even though some improvement in multifactor productivity or technical efficiency was measured, the evidence from this estimation shows that relative price efficiency overall did not improve; while labor inputs have converged somewhat, the price inefficiency for capital inputs has only worsened. While the competitive bidding system significantly improved the price efficiency of both capital and labor inputs relative to material inputs, the contracted responsibility system did not. This price inefficiency was significantly greater in the interior provinces relative to the coastal provinces.

This paper also introduced estimates of the variances of the relative shadow price ratios calculated from the generalized cost function, and these variances showed no sign of convergence in response to reform. While the bidding reform was consistent with a reduced variance for labor's shadow price ratio, and the contracted responsibility system was consistent with a lower variance for the shadow price ratio of capital, the general trend for both was significantly upward, not downward.

Of course, this conclusion cannot be extended too far. It is possible that there may still be uncorrected problems with the data. The construction sector may not be indicative of the rest of the economy; it does not generally sell its product directly to the consumer, though this is beginning to change, and nor is the construction sector in any country renowned for remarkable technological progress. Enterprise convergence may be hidden in the aggregate data, so that while provinces become less alike, enterprises within those provinces could be becoming more alike. More impressive results might be available if it were possible to get consistent and complete data for years prior to 1985. Future research is needed to test the generality of these conclusions; if this research shows that these results apply as well to state enterprises in other parts of the Chinese economy, then it appears that the reformers who are promoting more drastic enterprise reforms have a very strong case.
REFERENCES


