ARE WAGE INCREASES IN CHINESE STATE INDUSTRY EFFICIENT?
PRODUCTIVITY IN NANJING'S MACHINE-BUILDING INDUSTRY

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Since China's economic reform began, wages in state enterprises have increased at rates much faster than the rate of price inflation. This paper investigates the source of this rapid wage increase for a sample of Chinese state-owned machine-building enterprises to determine whether increased wages can be best explained by changes in productivity, changes in the output market, or changes in input markets. CES production function estimates find the marginal product of labor was stagnant between 1980 and 1992 but initially higher than wages. Rising wages were therefore consistent with other evidence that the reform process cost the state sector its labor monopsony. (JEL: P31)

1. INTRODUCTION

Do real wage increases in Chinese state-owned industrial enterprises simply reflect productivity improvements, or are other factors at work? Recently published data for 1997 (SSB, 1998), show that since 1978, during the start of the post-Mao economic reforms in the People’s Republic of China, wages in state industry have risen by an average annual rate of about 12.3%. This is faster than the 8.6% average annual increase in the official urban retail price index over the same period, and considerably faster than the 4.3% average annual increase in the output prices for state industry. Meanwhile, the traditional state sector’s share of industrial output has fallen from 78% to 26%, and there are mounting financial losses in the state sector.

The answer to this question is crucial to addressing the long-run survival of state-owned enterprises, the intended cornerstone of China’s emerging Shehuihui Shibie Xingji (Socialist Market Economy). Some scholars, most notably Kornai (1992), argue that rising state sector wages result from “wage drift” as economic reforms expand the autonomy given to state firms with soft-budget constraints and inappropriate managerial incentives. Lacking the fear of bankruptcy and personal loss faced by private owners, state managers prefer to keep their labor force pacified with higher wages, even though worker productivity may be stagnant or declining.

However, the erosion of monopoly power previously held by China’s state-owned enterprises in the manufacture of industrial goods can also explain the state sector’s relative decline (Naughton, 1992). Competition should lead to falling relative prices, rising output, and falling economic profits. Since state firms have significantly higher social overhead than do entering firms, competition may lead to losses even if productivity is improving. Since the hypothesis of monopoly erosion helps to explain falling profits but not rising wages, this paper extends this argument to consider whether reforms may have also cost the state its monopsony hiring position in labor markets; as non-state enterprises compete with state firms for skilled labor, the state firm may be forced to pay its workers more simply to retain them.

This paper examines the behavior of wages relative to the marginal product of labor in order to understand state firm responses to reform incentives. Using data collected from a sample of 20 enterprises in the machine-building industry of Nanjing, a large Chinese city, the relationship between wages and the value of labor’s marginal product is examined using

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a CES production function model. Both interview and econometric results strongly support the hypothesis that rising real wages reflect neither productivity improvements nor wage drift, but the loss of the state industrial labor monopoly.

II. THE STATE ENTERPRISES' INEFFICIENCY

Despite the dramatic economic transformation and improved performance of the Chinese economy since reform began, by now it is widely recognized that state-owned industrial enterprises have been more of a drag than a vanguard in this evolutionary process. Though the deflated value of the state sector's gross output in the industrial sector (including mining, manufacturing, and utilities) rose by over 7% per year, the non-state sector grew much faster. Collective firms, mostly including rural township and village enterprises (some of which may be quasi-private), now produce a larger share of industrial output than does the state sector. Production from firms under private, foreign, and joint-venture ownership has grown from less than 0.5% in 1980 to almost 20% by 1997. According to Parker (1995), average labor productivity in the non-state industrial sector was rapidly catching up to the state sector by the early 1990s, and by 1992 may have even surpassed it in real terms, in spite of the fact that the state sector continued to receive the lion's share of capital investment through the state's monopoly on banking.

By 1994, two years after the leadership announced plans for restructuring the state sector (Parker, 1995), over half of China's state-owned enterprises were reported to be losing money, and a quarter of the state workforce was considered surplus. Officially, government subsidies for loss-making enterprises totaled almost 32 billion yuan in 1995, only 5% of government revenue; however, enterprises are also subsidized through soft taxation and bank loans that can never be repaid, so this subsidy figure is likely understated. By 1995, almost a quarter of the loans held by China's largest banks were classified as nonperforming (Lardy, 1998).

Following up on initial studies by Chen et al. (1988b) and others who find multifactor productivity improving at rates of 5% per year or more, Jefferson and Rawaki (1994) argue that state firms became significantly more productive once economic reform improved the marginal role of markets and increased the firm's autonomy. However, other recent studies conclude that the preponderance of evidence points towards a state sector with almost stagnant technological progress and significantly rising expenditures (see Woo, 1997). In the construction sector, Parker (1997) finds that large and medium state enterprises had initially rapid rates of multifactor productivity improvements slowing to under 1% per year by 1992, while the marginal product of both capital and labor continued to decline below their factor prices.

Even after formal directive planning has been significantly reduced in favor of more firm autonomy, state enterprises still lack the incentives of private firms or even other socialist forms of ownership. State enterprises are required to be more than productive enterprises; they provide not only relatively secure employment, but also directly provide housing, education, health care, food, and even public security. According to this view, managers try to keep their workers content by increasing nonproductive investments and letting wages drift upwards at rates faster than productivity improvement, sacrificing profits because soft budget constraints allow them to do so.

After reform began, enterprises were allowed to keep a rising share of profits, but investment expenditures have still not been based on a reasonable assessment of capital's marginal product. Indeed, the net value of fixed assets in state industry increased ninefold through 1996, an average increase faster than gross output even once decomposed into annual increments and deflated. In addition, the share of reported "nonproductive" investment on housing and other amenities increased while the productive capital stock became increasingly obsolete. Kornai (1992, p. 227) argues that wages in the traditional socialist enterprise tend to spontaneously drift upwards through a pattern of leapfrogging, as groups of workers bargain with managers, and managers bargain with their superiors. In his view, giving the state firm more autonomy without correcting the institutional environment that softens its budget constraint leads to unchecked wage drift, declining state profitability, and increasing use of the state budget to subsidize failing firms.

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Naughton (1995) offers another compelling explanation for falling profits in Chinese state industry. As part of an effort to improve living standards, policymakers effectively dismantled the rules giving state industrial firms virtual monopolies in their output markets. Urban and rural collective enterprises could now produce goods once forbidden to them, and even state firms could increasingly enter into markets once reserved for others. Naughton (1992) documents that entry occurred where the state earned its highest profit rates and argues that the resulting competition from other state firms and from the growing non-state sector led to dramatically rising output at relatively lower prices and to a rapid decline in monopoly profits. Losses by the state sector, in this view, are the result not only of competition from rural areas but also of the excess social welfare burden borne by the state firms due to the traditionally privileged position of state workers.

Interviews in the Nanjing Machine Building Industry point to an extension of Naughton’s argument. Managers complained that their best workers were leaving them, breaking what were seen as implicit contracts between firm and worker. One manager explained the laborious process of getting rid of poor workers, and yet even without the firm’s official permission, some workers were failing to show up for work and were moving elsewhere. Similar interviews at rural township and village enterprises in southern Jiangsu province turned up similar results: respected managers would explain how they were hired away from urban state firms, and the author was told of dormitories being built for skilled workers hired away by higher pay. State enterprises were not only monopoly producers of industrial products, they were also monopoly employers in the labor market for skilled industrial workers, particularly given the rigidities of the labor allocation system.

There may be other reasons for rapidly rising wages. Lardy (1983, p. 165) estimates that a significant component of the real pay state workers receive was composed of ration coupons, cheap housing, free medical care, and other subsidies from the social welfare role of the state firm. In the past decade, however, much of the institutional structure of these subsidies has been weakened. Agricultural reforms have led to the dismantling of the food rationing system, as even grain is increasingly sold in markets. Medical care is slowly being changed into a fee-for-service basis, especially for higher-quality services. Housing reforms intend to force urban workers to purchase their residences by threat of rising rents. These reforms alone would lead to great discontent in urban areas, unless they were being monetized into the wage payment. However, while monetization of the wage would mean a rising observed wage, it would not necessarily mean that the total cost to the enterprise would rise. Instead, wages would appear to rise while other costs would appear to fall; wage monetization would therefore explain wage increases but fails to account for declining profits unless past nonmonetary subsidies were being passed through the firm to others, such as the central government or farmers providing goods at a below-market price, a possibility more likely for grain but less likely for housing.

Suppose that a state enterprise does attempt to maximize profit but is subject to a number of constraints and conditions not found in the typical competitive market. Profit is defined as:

\[ \pi = p_k(q, k, l, m) - r^*k - \frac{1}{l} p^* l - p^*_m l, \]

where \( p_k \) and \( p_m \) are the price deflators for outputs and intermediate material inputs, respectively. \( q \) is output, \( k \) is capital, \( l \) is labor, \( m \) is material, and \( r^* \) and \( w^* \) are the actual, but unobserved, prices for capital and labor. Output, of course, is a function of capital, labor, and material inputs. If the state has monopoly power, then output price is a function of output. If the state has monopoly power, then the wage rate is a function of labor. Assume that \( w^* = w + h \) and \( r^* = r + s + h / l \), where \( w \) and \( r \) are the observed factor prices for labor and capital, \( h \) includes nonmonetary payments to labor that are observed as capital costs, and \( s \) includes implicit subsidies through soft loans. Assume further that material inputs may be limited because of inefficiencies in the state distribution system and administratively-determined prices, and let \( \lambda \) be the Kuhn-Tucker multiplier (i.e., the marginal value of slack). Defining \( q_k, q_l, \) and \( q_m \) as the marginal products of capital, labor, and
material, respectively, letting $\zeta_{wd} < 0$ be the own-price elasticity for output demand, and letting $\zeta_{wd} > 0$ be the own-price elasticity for labor supply, profit maximization would lead to the following three conditions for each factor's observed ratio of the "shadow price" (the value of marginal product) to the observed factor price:

\begin{align*}
\frac{P_a}{r} &= \overline{z}_w = \left( \frac{r - s - h \beta k}{r} \right) \left( \frac{1}{1 + \zeta_{wd}} \right), \\
\frac{P_w}{w} &= \overline{z}_w = \left( \frac{w + h}{w} \right) \left( \frac{1 + \zeta_{wd}}{1 + \zeta_{wd}} \right), \\
\frac{P_m}{w} &= \overline{z}_w = \left( \frac{1 + \lambda \mu}{w} \right) \left( \frac{1 + \zeta_{wd}}{1 + \zeta_{wd}} \right),
\end{align*}

Thus, even if the state firm chooses to maximize profits, these shadow price ratios ($\overline{z}_w$, $\overline{z}_w$, and $\overline{z}_w$) may deviate significantly from unity under the constraints. Capital's ratio may be less if $s$ or $h$ is positive, or greater if $\zeta_{wd}$ is negative but not perfectly elastic. Labor's ratio may be greater if $h$ is positive, $\zeta_{wd}$ is positive but not perfectly elastic, or $\zeta_{wd}$ is negative but not perfectly elastic. Material's ratio may be greater if material is in short supply or if $\zeta_{wd}$ is negative but not perfectly elastic. The hypotheses, then, can be divided into four groups, each of which points toward a different pattern of relationships between factor prices and the value of marginal product, particularly in the labor market.

(i) If wage increases are a response to rising productivity in the state firm, then significant productivity improvements should be observed; since wages are rising faster than other factor prices, productivity improvements should be especially correlated with changes in labor inputs. However, this should not affect labor's shadow price (wage) ratio.

(ii) If wage drift is the source of wage increases, then the state enterprise is clearly not maximizing profits. Not only should labor's shadow wage ratio fall because of the rise in wages, but it should also be less than one as wages exceed the value of marginal product. Consistent with this hypothesis, evidence suggests that capital investment is also subject to a soft budget constraint, causing a low observed shadow price ratio for capital.

(iii) If gradual erosion of the state industrial monopoly is responsible for declining profits (that is, $\zeta_{wd} \to -\infty$), then one should not only observe evidence of a decline in relative output prices but also a decline in the shadow price ratio for all inputs towards unity.

(iv) If gradual erosion of the state labor monopoly is responsible for declining profits (that is, $\zeta_{wd} \to \infty$), then not only should the real wage rise, it should converge towards labor's marginal product. Labor's shadow wage ratio should thus decline towards unity. Wage monetization is also consistent with this, but this alone would not account for declining profitability, since presumably $h$ would fall as $w$ rose while $w^*$ (and $r^*$) would be unaffected.

These hypotheses are intended to explain both wage increases and falling profits, since they may be correlated. Monopoly erosion can explain the latter but not the former, while rising labor productivity, wage drift, monopoly erosion, and wage monetization can explain the former, but not always the latter. Thus, these hypotheses are not all mutually exclusive.

III. THE NANCHANG MACHINE BUILDING BUREAU

This study uses data from fieldwork conducted in Nanchang (Nanking) during 1994. Though a relatively small and somewhat more profitable sample, the 20 state-owned enterprises in the sample are in many ways representative of Chinese heavy industry in a traditional monopoly sector, for an important industry in an important location.

Nanjing is the capital city of Jiangsu province, a small and relatively prosperous province bordering Shanghai on China's east coast. Long an important city, Nanjing was the national capital of China both under the Song (960–1279) and during the early Ming Dynasty. Currently it is China's ninth largest city. Even though it contains less than 6% of China's population, Jiangsu province received over 11% of foreign investment contracted towards specific provinces in 1992, and Jiangsu is China's largest producer of industrial GDP in China.

Machine-building accounts for almost 10%
of the gross value of state enterprise industrial output in China and is a crucial industry in any rapidly industrializing economy. In the former USSR, for example, Gorbachev’s policy of uskorenie (acceleration) largely failed because of a bottleneck in this sector. In China, machine-building enterprises are typically large traditional factories under the state’s hierarchical organizational structure. At the municipal level, these enterprises answer to a bureau that is responsible to the municipal and provincial governments. As producers of heavy industrial equipment, they produce largely for the benefit of other state enterprises, and there are significant technological barriers to entry. However, beginning in the 1980s, they still faced competition from other state enterprises, foreign imports, and foreign joint-ventures.

Nanjing’s Machine-Building Bureau administers 59 state-owned enterprises producing industrial goods for domestic and foreign use, along with five sales companies and 15 specialized research institutes. These factories produce goods such as large drills, hoists, motors, turbines, furnaces, capacitors, compressors, train cars, and trucks. In 1993, almost four billion yuan (approximately $500 million U.S.) worth of output was produced by these enterprises. During the first half of 1994, the author visited many of these factories, interviewed managerial personnel, and collected statistical data from 20 enterprises comprising half of the total output produced under the bureau. Data was collected for four years—1980, 1985, 1989, and 1992—to enable a comparison over time.

Table 1 summarizes some of the data for the last year in this series in nominal terms. These data must be deflated in order to make meaningful estimates of labor’s shadow wage ratio. To deflate output, an implicit price index for Jiangsu’s machine-building industry is derived from nominal and real output reported in the Chinese Statistical Yearbooks. The possibility that this deflator may underestimate the true rate of inflation will be considered later. Since only the annual increment of capital must be deflated, following Jefferson et al. (1992), a procedure is used that decomposes annual investment and depreciation based on reported depreciation rates and changes in the original value and net value of fixed assets, deflates investment by a weighted price index for both the machine-building and the construction-materials industries, and then reconstructs an adjusted “real” capital stock series for each enterprise. In creating their capital deflator, Chen et al. (1988a) further decompose investment into four components, and then deflate each one separately before reconstructing the capital series. However, the analysis here lacks sufficient data to perform that procedure.

Material inputs are deflated using the overall factory price index of industrial products. Before they can be deflated, materials inputs are calculated as the difference between gross and net output value, adjusted for nominal

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**TABLE 1**

A Partial Summary of Data Collected, 1992

<table>
<thead>
<tr>
<th></th>
<th>Sum</th>
<th>Average</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industrial output:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross value*</td>
<td>1,808,908</td>
<td>90,045</td>
<td>23,000</td>
<td>389,920</td>
<td>85,173</td>
</tr>
<tr>
<td>Net value*</td>
<td>529,720</td>
<td>26,486</td>
<td>4,800</td>
<td>73,500</td>
<td>19,630</td>
</tr>
<tr>
<td><strong>Fixed assets:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Original value*</td>
<td>1,163,610</td>
<td>58,318</td>
<td>5,310</td>
<td>234,216</td>
<td>56,245</td>
</tr>
<tr>
<td>Net value*</td>
<td>307,630</td>
<td>40,232</td>
<td>2,950</td>
<td>176,730</td>
<td>39,918</td>
</tr>
<tr>
<td>Pre-tax profits*</td>
<td>164,882</td>
<td>8,244</td>
<td>0,980</td>
<td>24,186</td>
<td>6,382</td>
</tr>
<tr>
<td>Taxes*</td>
<td>38,956</td>
<td>3,753</td>
<td>0,350</td>
<td>10,592</td>
<td>2,732</td>
</tr>
<tr>
<td><strong>Employees</strong></td>
<td>45,380</td>
<td>2,569</td>
<td>430</td>
<td>5,882</td>
<td>1,534</td>
</tr>
<tr>
<td>Average wage (yuan/year)</td>
<td>3,713</td>
<td>2,365</td>
<td>5,467</td>
<td>1,174</td>
<td>674</td>
</tr>
</tbody>
</table>

*Million yuan (Rmb/nian)
fixed asset depreciation. Following Moroney and Trapani (1981), capital's "price" is estimated as the residual of observed cost less material and labor expenditures, divided by the adjusted capital stock. For purposes of estimation and ease of interpretation, deflated output and input vectors are divided by their means, and price deflators and prices are adjusted accordingly. Finally, a time variable is calculated as the year less 1980.

Table 2 shows the resulting data in average annualized rates of change between years in the sample. These trends are generally consistent over time, in spite of China's economic slowdown in the later 1980s, and consistent with patterns observed elsewhere in the Chinese economy. Both output and material prices grew more slowly than the overall retail price index, consistent with the argument that industrial producers experienced a relative decline in prices as a result of monopoly erosion. The average wage rose very rapidly, while the labor force grew very slowly, consistent with either the monopoly erosion argument or the wage drift argument. The profit rate declined by over half from 1980 to 1992 for this sample, from 19% to 9%, and wage increases account for most of this decline in profits; if the average wage had only increased at the rate of retail price inflation (which still exceeds the industrial output price inflation rate), the profit rate would have only declined to 15%. Output grew faster than capital and labor, but more slowly than deflated material inputs, and the deflator for materials grew slightly faster than the deflator for output.

Is the wage exogenously determined, or endogenous to the firm? A simple logarithmic regression of the wage-price ratio on possible explanatory factors finds that the deflated wage is not significantly correlated with profits, multifactor productivity, or export share; however, the wage is positively correlated with output, capital stock, and time, and negatively correlated with the size of the labor force. These results are not only consistent with wage drift, but also with the distribution of profits by a labor-managed enterprise if the reported profits are the remainder after distribution to the workers. The results strongly suggest that wages are not determined in relatively exogenous labor markets.

These enterprises have profit rates that are considerably larger than those found by Parker (1996) for China's construction sector, which perhaps is evidence of their relative monopoly position. However, profits are still declining as wages rise. During this same period, taxes fell from an average 79% of profits in 1980 to 45% in 1992. A simple regression of the profit rate on possible explanatory factors finds that in addition to a significant downward time trend, profits were positively correlated with an index of multifactor productivity (explained and calculated later in this paper) but not significantly related to output or inputs. The profit rate was uncorrelated with the tax rate, even though the observed tax rate was significantly progressive beginning in 1985.

Investments too have continued to rise. The capital stock, even after deflation, has grown by over 10% per year on average. However, a simple regression of investment on possible explanatory variables fails to find any significant correlation between investment and the profit rate, multifactor productivity, or exports.

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Instead, investment is positively correlated with the enterprise's labor force, either current or lagged, and it is negatively correlated with lagged capital. This suggests that the Nanjing Machine-Building Bureau still allocates capital to the enterprises on the basis of employment, and with a strong tendency to equalize capital among enterprises. The regression results are further backed up by managerial statements made during interviews.

Perhaps because of these investment patterns, the enterprises visited had considerable excess capacity. One factory manager of a turbine manufacturer, for example, said that he was producing steam turbines at \( \frac{2}{3} \) of his factory's capacity, and gas turbines at less than \( \frac{1}{3} \) of capacity. Tour after tour during working hours found idle equipment and machinery operators, quiet factories, and workers sent home early. This suggests that the marginal product for labor may also be close to zero (though there may be a difference between the marginal product of an additional worker versus that of another hour of work). Factory administrators expressed their desire for foreign investment, not just because of raw investment hunger, but because they believed that foreign investment would provide up-to-date technology to make their products more desirable, and an export market already developed by their foreign partner. At the time of this fieldwork, managers claimed that talks were proceeding with foreign corporations such as Navistar, Siemens, Westinghouse, and General Electric. These negotiations were being handled by the leaders of the Nanjing Machine Building Bureau.

IV. ESTIMATING THE PRODUCTIVITY OF LABOR

In order to estimate the relationship between wages and labor productivity and to determine whether multifactor productivity has increased for these enterprises, this section specifies a production function equation for industrial output by the enterprises under the Nanjing machine-building bureau. From this production function, an equation is derived to estimate the wage efficiency of labor, and then these two equations are estimated simultaneously before testing and calculating indicators for efficiency and the relationship between wages and productivity.

A. The Production Function

The production function is the most commonly used specification of the firm's technology, though it is often criticized for the potential correlation between inputs (particularly capital) and the residual (see Varian, 1984, pp. 171–176). In this sample, at least, the capital stock does not appear to be correlated with firm efficiency (see Section III). The simple tests above also strongly suggest that the wage rate is endogenous to the firm, so alternative specifications (such as cost or profit functions) that rely on factor prices may not yield better estimates for these data.

Therefore, a production function is defined for the \( n \)th enterprise's deflated gross value of industrial output \( (q) \) at time \( t \) as a function \( \Phi \) of three inputs \( \{k, l, m\} \):

\[
\hat{q}_{nt} = \Phi_{nt}(y_{nt})
\]

where \( y = \{k, l, m\} \). Observed output is equal to the predicted level of output with error. Based on results from an initial generalized Box-Cox estimation (Berndt and Khaled, 1979), the error is specified as logarithmically normal, i.e.:

\[
\ln y_{nt} = \ln \Phi_{nt}(y_{nt}) + \epsilon_{nt},
\]

and \( \epsilon_{nt} \sim N(0, \sigma^2) \) is assumed to be an independently and identically distributed normal error.

The production function \( \Phi \) is defined as a CES (Constant Elasticity of Substitution) form, because in this case the CES fits the data better than either the translog or the generalized Cobb-Douglas logarithmic forms. This CES is specified as:

\[
\ln \Phi_{nt} = \alpha_{m} + \frac{\rho}{\rho - 1} \ln \left( \sum_{j=1}^{3} \alpha_{j} y_{jt} \right).
\]

where \( \alpha_{j} = \alpha_{0} + \alpha_{i} t \), and the intercept \( \alpha_{m} \) is assumed to be a function of time and enterprise-specific effects, so:

\[
\alpha_{m} = \alpha_{0} + \alpha_{1} t + \sum_{s=1}^{20} \Delta_{s} E_{s}.
\]
In this specification, the effects of the \( r \) variable have both Hicks-neutral and non-neutral components. The vector \( E \) contains dummy variables for the 20 individual enterprises in the sample, and \( \Delta \) is a vector of associated coefficients. Since the enterprise-specific differences cannot all be estimated separately from the scalar \( \alpha_r \), \( \Delta_r \) (for the most productive enterprise) is implicitly set to zero so that the other dummy variables reflect relative enterprise differences. The adding-up condition is then imposed, so that:

\[
\sum_{j=1}^{n} \alpha^{*}_{j} = 1.
\]

This is done by restricting \( \alpha_{m0} = 1 - \alpha_{m0} - \alpha_{m0} \), and \( \alpha_{m} = - \alpha_{m0} - \alpha_{m0} \). Given the adding-up condition, this production function exhibits constant returns to scale if \( \rho = 1 \). The Allen-Uzawa elasticity of substitution (\( \sigma \)) is equal to \( 1/(1 - \rho) \), and if \( \rho \leq 1 \), then this function is quasi-concave in its factors of production (if \( \rho \leq 1 \), then this function is also concave).

B. The Wage Efficiency Equation

In a firm that maximizes profit without constraint for a given set of exogenously-determined input and output prices, labor’s wage equals the output price times the marginal product of labor, and a nonnegative marginal product is a fundamental first-order condition for the production function. Assuming \( \mu > 0 \), a nonnegative marginal product is ensured if \( \alpha^{*}_{c} \geq 0 \Rightarrow \gamma \). For labor \( \gamma \) is the second element of \( \gamma \), the marginal product from this CES specification is:

\[
\frac{\partial \tilde{q}_{it}}{\partial \gamma_{it}} = \Phi_{it} \\
= \exp(\gamma_{it}) \mu \alpha^{*}_{m} \left( \sum_{j=1}^{n} \alpha^{*}_{j} \tilde{v}_{j} \right)^{\frac{\rho - 1}{\rho - 1}}.
\]

This paper uses the term “shadow wage” for the value of labor’s marginal product under the assumption that the enterprise is maximizing according to a price for labor that is unobserved by the econometrician, but is nonetheless real to the enterprise. Monopsony power, for example, implies a marginal labor expenditure in excess of the marginal wage rate. To allow for divergence from the labor-use efficiency, the shadow wage ratio \( (\xi) \), which is the ratio of the value of labor’s marginal product to its wage rate, is defined as a non-negative function not necessarily equal to one.

The exponential function captures this best:

\[
\xi_{it} = \frac{\tilde{q}_{it}}{w_{it}} = \exp(\gamma_{it} \mu + \mu_{it}).
\]

The shadow wage equation contains an error term \( \eta_{it} \sim N(0, \sigma^{2}) \) that is also assumed to be independent and identically distributed. Dropping the \( s \) and \( t \) subscripts, equations (8) and (9) are rearranged into:

\[
\ln \frac{\tilde{w}}{P_{t}} = \alpha^{*}_{o} + \ln \mu + \ln \alpha^{*}_{m} + (\rho - 1) \ln \tilde{\pi}
\]

\[
+ \left( \frac{\rho - 1}{\rho} \right) \ln \left( \sum_{j=1}^{n} \alpha^{*}_{j} \tilde{v}_{j} \right) - \xi_{0t} - \xi_{it} t - u.
\]

Many of these parameters are already estimated in the production function specified in equations (4) and (5), and thus the shadow wage parameters could be estimated in a two-step process. However, estimating the two equations simultaneously, should improve the efficiency of the estimation, since the coefficients are shared. If the errors \( c \) and \( u \) are contemporaneously correlated (i.e., if an unobserved event that affected total factor productivity also affected labor productivity), then a seemingly-unrelated regressions approach is preferred. Table 3 compares these alternatives.

C. Measures of Efficiency and Productivity Change

From the estimates of the production function and wage equation, measurements are calculated for the relative productivity of these enterprises, how this productivity changes over time, and how efficiently these enter-
### TABLE 3

**CES Production/Wage Equation Estimates**

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>A. Unrestricted Simultaneous Equations</th>
<th>B. Restricted Simultaneous Equations</th>
<th>C. Restricted Two-Step Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Estimate</td>
<td>Standard Error</td>
<td>Mean Estimate</td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.969</td>
<td>(0.038)**</td>
<td>1.0</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.872</td>
<td>(0.043)**</td>
<td>0.891</td>
</tr>
<tr>
<td>$\alpha_\theta$</td>
<td>0.006</td>
<td>(0.004)*</td>
<td>0.004</td>
</tr>
<tr>
<td>$\alpha_0$</td>
<td>-0.008</td>
<td>(0.013)</td>
<td>0.0</td>
</tr>
<tr>
<td>$\alpha_\phi$</td>
<td>0.001</td>
<td>(0.002)</td>
<td>0.0</td>
</tr>
<tr>
<td>$\alpha_\theta$</td>
<td>0.102</td>
<td>(0.035)**</td>
<td>0.107</td>
</tr>
<tr>
<td>$\alpha_\phi$</td>
<td>-0.009</td>
<td>(0.001)</td>
<td>0.000</td>
</tr>
<tr>
<td>$\alpha_{\alpha\phi}$</td>
<td>0.906</td>
<td></td>
<td>0.893</td>
</tr>
<tr>
<td>$\alpha_{\theta\psi}$</td>
<td>-0.000</td>
<td></td>
<td>-0.000</td>
</tr>
<tr>
<td>$\xi_0$</td>
<td>0.559</td>
<td>(0.356)</td>
<td>0.642</td>
</tr>
<tr>
<td>$\xi_1$</td>
<td>-0.073</td>
<td>(0.015)**</td>
<td>-0.068</td>
</tr>
<tr>
<td>$\alpha_\theta$</td>
<td>0.144</td>
<td>(0.070)**</td>
<td>0.173</td>
</tr>
<tr>
<td>$\alpha_\phi$</td>
<td>-0.950</td>
<td>(0.083)</td>
<td>-0.790</td>
</tr>
<tr>
<td>$\delta_\phi$</td>
<td>-0.982</td>
<td>(0.075)</td>
<td>-0.299</td>
</tr>
<tr>
<td>$\delta_\theta$</td>
<td>-0.146</td>
<td>(0.089)*</td>
<td>-0.192</td>
</tr>
<tr>
<td>$\delta_\psi$</td>
<td>-0.990</td>
<td>(0.087)</td>
<td>-0.128</td>
</tr>
<tr>
<td>$\beta_\phi$</td>
<td>-0.093</td>
<td>(0.069)</td>
<td>-0.089</td>
</tr>
<tr>
<td>$\beta_\theta$</td>
<td>-0.155</td>
<td>(0.072)**</td>
<td>-0.165</td>
</tr>
<tr>
<td>$\beta_\psi$</td>
<td>-0.139</td>
<td>(0.072)*</td>
<td>-0.150</td>
</tr>
<tr>
<td>$\beta_{\alpha\phi}$</td>
<td>-0.193</td>
<td>(0.067)**</td>
<td>-0.189</td>
</tr>
<tr>
<td>$\beta_{\alpha\psi}$</td>
<td>-0.263</td>
<td>(0.080)**</td>
<td>-0.290</td>
</tr>
<tr>
<td>$\beta_{\theta\psi}$</td>
<td>-0.204</td>
<td>(0.074)**</td>
<td>-0.215</td>
</tr>
<tr>
<td>$\beta_{\theta\phi}$</td>
<td>-0.206</td>
<td>(0.075)**</td>
<td>-0.225</td>
</tr>
<tr>
<td>$\beta_{\phi\psi}$</td>
<td>-0.218</td>
<td>(0.074)**</td>
<td>-0.188</td>
</tr>
<tr>
<td>$\beta_{\phi\psi}$</td>
<td>-0.338</td>
<td>(0.075)**</td>
<td>-0.351</td>
</tr>
<tr>
<td>$\beta_{\phi\phi}$</td>
<td>-0.146</td>
<td>(0.071)**</td>
<td>-0.157</td>
</tr>
<tr>
<td>$\beta_{\psi\psi}$</td>
<td>-0.279</td>
<td>(0.070)**</td>
<td>-0.281</td>
</tr>
<tr>
<td>$\beta_{\psi\psi}$</td>
<td>-0.412</td>
<td>(0.068)**</td>
<td>-0.400</td>
</tr>
<tr>
<td>$\beta_{\psi\phi}$</td>
<td>-0.303</td>
<td>(0.078)**</td>
<td>-0.272</td>
</tr>
<tr>
<td>$\beta_{\psi\psi}$</td>
<td>-0.255</td>
<td>(0.068)**</td>
<td>-0.245</td>
</tr>
<tr>
<td>$\beta_{\phi\psi}$</td>
<td>-0.354</td>
<td>(0.069)**</td>
<td>-0.327</td>
</tr>
</tbody>
</table>

| $\ln\bar{y}$ | 157.4  | 156.4  | 130.1  |

** and * indicate significance at the 5% and 10% levels, respectively.
prices are choosing their inputs to minimize observed costs. First, a measure of multifactor productivity \((M)\) is calculated for each observation:

\[ M = \frac{\eta}{\tilde{\delta} \times (V_p)} \]  

The function \( F \) uses mean parameter estimates to provide a fitted estimate, with the coefficients for time \( t \) and enterprise differences \( E \) all set to zero. This ratio is then normalized by dividing each \( M \) by the maximum observed, resulting in a relative index with a maximum value of unity.

Change in multifactor productivity over time can be observed by changes in the \( M \) index, or it can be calculated as the first derivative of the estimated production function. In log form, this gives an approximate rate of change \( g \) per year:

\[ g_t = \frac{\partial \ln \eta}{\partial t} \]

\[ = \alpha_t + \frac{\mu}{\rho} \left( \sum_{j=1}^{J} \alpha_j V_j \right) \left( \sum_{j=1}^{J} \alpha_j^2 V_j \right)^{-1} \]

The shadow wage ratio for labor can be directly reported from the fitted values of \( \xi \), but for capital and material inputs the shadow price ratios first require calculation of their marginal products.

Since the CES function can be inverted to solve for the minimum cost as a function of input prices and output, the index of input price efficiency can be calculated as the ratio of minimum cost to observed cost:

\[ \eta = \left( \frac{\eta}{\alpha_0} \right)^{\frac{1}{1-\sigma}} \left( \sum_{j=1}^{J} \left( \alpha_j \right)^{1-\sigma} W_j \right)^{\frac{1}{1-\sigma}} \left( \sum_{j=1}^{J} W_j V_j \right)^{-1} \]

where \( W = [w_k, w_m, w_l] \), and \( \alpha_0 \) and \( \alpha_j \) for \( j \) are again functions of \( t \).

V. ESTIMATION AND RESULTS

Because they share most of their coefficients, the production function in equation (4), as specified in equations (5), (6), and (7), is estimated simultaneously with the wage efficiency equation given in (10). These equations are nonlinear, and since the error terms \( e \) and \( u \) may be contemporaneously correlated, this system of two equations is estimated using an iterative Davidson-Fletcher-Powell algorithm that approximates Zellner's seemingly unrelated least squares technique, and converges towards maximum likelihood. Starting values are attained with an initial wage-efficient Cobb-Douglas linearization (since the limit of the CES form as \( \rho \to 0 \) is Cobb-Douglas), and convergence is obtained within 100 iterations. Alternative starting values are attempted to check that a global rather than a local maximum is being reached. After numerous attempts, no higher maximum could be found.

Table 3 shows three versions of the parameter estimates. Column A includes results for an unrestricted simultaneous estimation. This is tested for linear homogeneity by evaluating the test-statistic of the hypothesis \( \mu = 1 \). Though the initial parameter estimate implies weakly decreasing returns to scale, the hypothesis of constant returns cannot be rejected at 10% significance. This is verified by testing this hypothesis again when all enterprise-level differences are restricted to zero, and it is again accepted. Therefore, there is no evidence of systematic correlation between productivity and scale in this sample of enterprises, and constant returns to scale may be safely imposed. Capital's marginal product is negative for 75% of the observations, but the hypothesis that capital's marginal product equals zero cannot be rejected. A low or insignificant marginal product of capital may be evidence that investment is not based on economic conditions. However, such a negative marginal product of capital is a violation of standard curvature conditions, and not only does this make factor price efficiency impossible to calculate (since any root of a negative number is imaginary), it makes estimates of multifactor productivity suspect since the isoquant may be upward-sloping.

In column B, constant returns to scale are imposed (by setting \( \mu = 1 \)) together with a zero marginal product of capital (\( \alpha_{00} = \alpha_0 = 0 \)).
TABLE 4
Estimates of Alternate Production Functions
(Constant Returns to Scale)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>A. CES</th>
<th>B. Translog</th>
<th>C. Cobb-Douglas</th>
<th>D. CD-CES</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Estimate</td>
<td>Standard Error</td>
<td>Mean Estimate</td>
<td>Standard Error</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.896</td>
<td>(0.031)**</td>
<td>0.007</td>
<td>(0.005)</td>
</tr>
<tr>
<td>$\alpha_d$</td>
<td>0.006</td>
<td>(0.003)**</td>
<td>0.001</td>
<td>(0.052)</td>
</tr>
<tr>
<td>$\alpha_w$</td>
<td>-0.012</td>
<td>(0.012)</td>
<td>0.001</td>
<td>(0.004)</td>
</tr>
<tr>
<td>$\alpha_d$</td>
<td>0.122</td>
<td>(0.023)**</td>
<td>0.125</td>
<td>(0.049)**</td>
</tr>
<tr>
<td>$\alpha_w$</td>
<td>-0.000</td>
<td>(0.002)**</td>
<td>0.009</td>
<td>(0.002)**</td>
</tr>
<tr>
<td>$\alpha_d$</td>
<td>0.990</td>
<td>0.874</td>
<td>0.417</td>
<td>0.498</td>
</tr>
<tr>
<td>$\alpha_w$</td>
<td>-0.001</td>
<td>-0.012</td>
<td>0.008</td>
<td>0.007</td>
</tr>
<tr>
<td>$\beta_d$</td>
<td>0.003</td>
<td>(0.036)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_w$</td>
<td>0.072</td>
<td>(0.017)**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta_d$</td>
<td>0.021</td>
<td>(0.013)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\xi_d$</td>
<td>0.766</td>
<td>(0.181)**</td>
<td>0.505</td>
<td>(0.326)</td>
</tr>
<tr>
<td>$\xi_d$</td>
<td>-0.071</td>
<td>(0.015)**</td>
<td>0.012</td>
<td>(0.010)</td>
</tr>
</tbody>
</table>

|                | 157.1   | 113.5       | 54.5            | 60.9       |

** and * indicate significance at the 5% and 10% levels, respectively.

Results of this restricted version are mostly identical to the unrestricted version, however, the statistical significance of $\alpha_d$ and some enterprise dummy variables falls, and the significance of $\xi_d$ rises. The decrease in the log-likelihood statistic is not statistically significant. For purposes of comparison, this restricted version is also estimated in a two-step process, instead of as a simultaneous system. Column C reports results. The log-likelihood statistic falls significantly, but the results are not qualitatively different, and thus the results of the restricted version in column B appear to be robust.

Table 4 reports the results for different functional forms of a constant-returns-to-scale production function that does not restrict the marginal product of capital to zero (the dummy variable parameters are not reported). These forms include the CES, translog, and Cobb-Douglas, along with another CES form in column D in which $\rho$ is restricted to 0.1 (since the limit of the CES as $\rho \rightarrow 0$ converges to the Cobb-Douglas, this is, more or less, a CES approximation of the Cobb-Douglas form). The CES form fits the data best. The translog form gives similar results for the $\alpha$ parameters, but the function is not concave in inputs, and many key parameters are insignificant. The Cobb-Douglas gives similar results for shadow wage parameters, but the estimate also yields a much higher rate of productivity growth. This is confirmed with the CES-CD approximation and may explain why estimates of productivity growth differ widely among studies: a flatter isoquant is less likely to interpret changes in the input mix as improvements in productivity. Studies that rely on the Cobb-Douglas form might therefore be biased toward estimates of higher rates of productivity improvement.

Table 5 summarizes the measures of efficiency and productivity change using calculated measures from the restricted version in column B of Table 3. Multifactor productivity is increasing at a rate of about 0.5% per year, and thus average productivity relative to best


TABLE 5

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multifactor productivity (M)</td>
<td>0.693</td>
<td>0.705</td>
<td>0.714</td>
<td>0.731</td>
</tr>
<tr>
<td>Partial rate of change (q)</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>Factor price efficiency (e)</td>
<td>0.735</td>
<td>0.742</td>
<td>0.765</td>
<td>0.778</td>
</tr>
<tr>
<td>Capital's shadow price ratio ((\lambda_c))^*</td>
<td>-0.054</td>
<td>-0.017</td>
<td>-0.005</td>
<td>0.086</td>
</tr>
<tr>
<td>Labor's shadow wage ratio ((\lambda_l))</td>
<td>1.903</td>
<td>1.348</td>
<td>1.023</td>
<td>0.831</td>
</tr>
<tr>
<td>Material's shadow price ratio ((\lambda_m))</td>
<td>1.498</td>
<td>1.474</td>
<td>1.409</td>
<td>1.337</td>
</tr>
</tbody>
</table>

*From the Unrestricted Version, since Capital's Shadow Price Ratio is zero in this Restricted Version.

practice in the sample rises from about 69% to 73% in 12 years. This ratio is only weakly significant in some versions, except in the Cobb-Douglas form as mentioned above. To test whether the growth of productivity was slowing over time, an alternative specification is estimated that includes an additional squared term for the time trend. This additional parameter is not significantly different from zero in any version. The relative differences in productivity are primarily between enterprises, not over time. Taking the natural exponents of the \(\lambda\) coefficients, the most productive (\(\lambda = 0\)) enterprise is on average 50% more productive than the worst performer (\(\lambda = -0.4\)).

Contrary to the findings of Parker (1996, 1997) for the construction industry, factor price efficiency in Nanjing's machine-building industry improved over time, again by about 0.5% per year, and it reached about 78% average price efficiency by 1992. Perhaps this difference can be explained by the fact that the machine building industry is a traditional state industry much more likely to have had monopoly and monopoly power in the early 1980s, while the construction sector has lower entry barriers and has been relatively more competitive with collective enterprises in both labor and output markets.

In this estimate, labor's shadow wage ratio was initially high, and declined as time went on until, by 1992, the value of marginal productivity fell below the wage; the decline in the shadow wage ratio was statistically significant in all cases but the translog (an estimate that violated concavity). Material's shadow price ratio also exceeded unity, which may indicate that material inputs remained in short supply, and this ratio also slowly converged towards unity, though much more slowly. Since capital's marginal product is restricted to zero in this version, Table 5 shows instead the shadow price ratio for capital from the unrestricted version in column A of Table 3. Consistent with the measures of improving price efficiency, capital's marginal product rises from negative values to positive, if insignificant, values by 1992.

These results find that productivity changes were Hicks-neutral, not correlated with labor, and not rising very significantly over time; thus, the hypothesis that rising wages are following productivity improvements is not borne out by the data. Wages rose faster than labor's value of marginal product (causing a falling shadow wage ratio), a result consistent with both the hypothesis that reform has led to the erosion of monopoly power and that of wage monetization (though the latter alone would not be sufficient to explain the decline in profitability). Since the shadow price ratio for material inputs also fell, though more slowly, the data are also consistent with the monopoly erosion hypothesis. At least until 1989, however, wage drift does not appear to be the best explanation for the falling shadow price ratio of labor, since factor price efficiency improved rather than declined.

Are these results robust for other specifications? Material inputs make up an average 60% of the enterprise's costs in this sample, but their estimated output elasticity is about 0.89. Because it is possible that the strong correlation between material inputs and output may bias the estimation results, an alternate version of the model is tested. Following Jeff...
ferson (1989, 1990) and Chen et al. (1988b), a net-value specification is estimated, where output is defined as net value-added (gross value less materials cost) and only capital and labor are factor inputs. This specification is not ideal. Parks (1971) strongly argues against the net value production function unless there is an a priori reason to believe that material (intermediate) inputs are either used in fixed proportions or are perfect substitutes with output. However, testing the sensitivity of the results is appropriate since it is a commonly-used form. The results, which are not reported, indicate that rising material inputs accounted for much of the output growth. Without materials, returns to scale appear excessively high, with a scale elasticity of 1.5, and total factor productivity rises at a rate of 12% per year. However, capital's marginal product is still zero or negative, productivity gains are still not correlated with labor, and labor's shadow wage ratio is still high and falling over time. The basic results appear to hold, and the hypotheses of monopoly and monopoly erosion still fit the results better here than does the wage drift hypothesis.

As shown in Table 2, the price deflator for material inputs rises faster than the price deflator for output. This is consistent with Jefferson et al. (1992), but Woo et al. (1994) argue that this may overstate the rate of improvement in multifactor productivity since the implicit value-added deflator may actually decline. Checking this requires calculating an implicit value-added deflator, approximated as $(p_q - \pi - w_m) / q - \pi / p_q - m$. Results indicate that this deflator is still increasing. However, to verify that the results of this paper are not artifacts of a rising materials-output price ratio, $w_m$ is set to $p_q$ and the system of equations is re-estimated. The results are qualitatively identical, with one exception: the joint hypothesis that multifactor productivity did not change over time cannot be rejected in any version of the model.

Finally, since the machine-building price deflator may underestimate actual inflation due to a new-products bias, the model was estimated again, replacing the machine-building price deflator with a faster-rising overall industrial price index. This affects both the deflation of output and of capital. The results again do not change much, except that the estimated productivity growth rate fell to an insignificant -0.4%. Different price assumptions thus make the rate of productivity improvement even less significant. Otherwise, alternative assumptions and specifications do not significantly affect estimates of the shadow wage ratio.

VI. CONCLUSION

This study examines data from the Nanjing machine-building industry, a traditional state industry in China, and uses a CES production function approach to estimate the relationship between wages and labor productivity as the primary factor affecting the decline of the state sector's profits. While it finds that multifactor productivity improvement was not very significant from 1980 to 1992, and that capital investment increased without relation to profitability, productivity, or a corresponding increase in output, findings also support Naughton's argument that a major source of falling profits in state industry was the erosion of their monopoly power. That is, non-state firms and state firms from other sectors have increasingly competed in producing higher-profit goods, and existing state firms have done poorly in the contest, perhaps as a result of their larger social burden.

While the marginal product of capital investment is still approximately zero in the case of Nanjing's machine building industry, the values of the marginal products of both labor and material inputs have converged towards factor prices. For labor, this is particularly true because wages have risen so much faster than either output or material prices. As a result, this study further extends Naughton's argument by finding evidence that the state has also lost its monopoly power over skilled industrial workers; as a result, state enterprises have been forced to increase wages. In spite of low productivity growth, in an effort to retain workers. Therefore state-owned enterprises have been forced to become more price efficient, at least in the labor market. The hypothesis that firm autonomy leads to wage drift and thus is responsible for declining profit rates appears to be contradicted by these estimates.

Economic reform appears then to have improved the price efficiency of state-owned enterprises, at least in the case of Nanjing's machine building industry, even as it made them less profitable. However, this improvement has
been in the firm’s environment rather than in the firm’s behavior. Minimal productivity growth and inefficient investment patterns suggest that managerial incentives for state enterprises still do not adequately yield profit-maximization. The policy implications of this are serious. Chinese reforms have improved the economy, but not the state-owned enterprises that the party leadership still believes are so fundamental to it. Unless investment spending is rationed through more exciting financial markets and greater numbers of state firms are allowed to go bankrupt, state firms are going to continue draining China’s budgetary and financial resources.

REFERENCES


Naughton, Barry, “Implications of the State Monopoly over Industry and its Relaxation,” Modern China, 18:1, 1992, 14-41.


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