Growth, Efficiency, and Convergence in China's State and Collective Industry
Author(s): Gary H. Jefferson, Thomas G. Rawski and Yuxin Zheng
Source: *Economic Development and Cultural Change*, Vol. 40, No. 2 (Jan., 1992), pp. 239-266
Published by: The University of Chicago Press
Stable URL: http://www.jstor.org/stable/1154196

Growth, Efficiency, and Convergence in China's State and Collective Industry*

Gary H. Jefferson
Brandeis University

Thomas G. Rawski
University of Pittsburgh

Yuxin Zheng
Chinese Academy of Social Sciences

I. Introduction

In China, as in the Soviet Union and Eastern Europe, economic reform initiatives seek to increase productivity by introducing elements of market-oriented policies and institutions into an economy formerly dominated by state planning. Efforts to evaluate the impact of reform of Chinese industry have focused on the measurement of productivity change in state enterprises.

This study expands the prior framework of analysis in several directions. Our investigation of productivity trends is not limited to state enterprises but includes quantitative comparisons with China's fast-growing collective industries, which contributed 36% of overall industrial output in 1988.[1] Unlike previous studies, our analysis works with gross rather than net output. This permits us to investigate changes in the productivity of intermediate inputs, which occupy a large portion of total costs in Chinese industry, as well as labor and capital. To do this, we develop a "quasi-frontier" estimation procedure which seems appropriate for comparisons of total factor productivity based on Chinese industrial data. Finally, we offer a quantitative perspective on the extent to which reform efforts have moved industrial resource allocation toward patterns expected of a market system.

The analysis confirms our previous finding, based on a restricted framework employing only labor, fixed capital, and net output, that multifactor productivity in state industry has risen substantially during

0013-0079/92/4002-0004$01.00

the reform period (1978–88) after stagnating for more than 2 decades.[2] We find that total-factor productivity in collective industry has grown more rapidly than comparable measures for state industry. Even with productivity growing in the range of 2.4% annually in the state sector and 4.6% in collective industry, factor accumulation emerges as the principal contributor to China's rapid industrial growth.

The most intriguing result of the present analysis concerns a tendency for factor returns to converge between the two segments of Chinese industry. In a market economy, we expect interaction between income-seeking buyers and sellers to equalize marginal returns to any resource used in several sectors of the economy. Central planning provides no comparable mechanism. A successful program of economic reform should generate evidence of gradual convergence in the marginal revenue product of similar inputs across multiple uses. Comparison of returns to labor and capital across state and collective industry shows some movement in the direction of convergence, suggesting that Chinese reform may have begun to affect the efficiency of resource allocation despite the limited spread of factor markets. The most surprising outcome of our study is the finding of near identity of the marginal revenue product of materials in state and collective industry even at the beginning of the reform period.

II. China's Industrial Structure

China's work force and industrial production are distributed over what may be, measured in terms of ownership, enterprise size, technologies, and product space, the world's most diverse industrial economy. At one end of the industrial spectrum, we find large state-owned factories. The central government's decisions about the allocation of labor, investment and materials, price controls, and performance targets extensively influence the operation of these enterprises. Most state-owned enterprises (SOEs) obtain resources and ship products through some combination of plan and market activity. At the margin, virtually all SOEs now have considerable choice in setting output levels, product mix, input combinations, and prices.

Further along the continuum of enterprise types lie collective enterprises (COEs), including both urban collectives and township-village enterprises (TVEs). These differ from state-owned units in that the legal right to residual earnings belongs to the local jurisdictions that organize these units rather than to the central government. Although most urban collective units come under the formal supervision of local governments, they operate largely outside the orbit of state planning and typically enjoy greater managerial and financial autonomy than state-owned firms.

At a greater distance from government supervision, China's township and village enterprises (*xiangzhen qiye*, or TVEs) operate with

TABLE 1

BASIC DATA ON STATE AND COLLECTIVE INDUSTRY, 1978 AND 1988
(Excluding Village-Level Industry)

	Number of Enterprises (Thousands)		Gross Output Value Current Yuan (Billions)		Year-End Employment (Millions)	
	1978	1988	1978	1988	1978	1988
State:						
Independent units	N.A.	72.4[b]	317.3	994.7[b]	30.4	42.6?
Total	83.7[a]	99.1[b]	342.1[c]	1,035.1[b]	31.4[d]	42.6[e]
Collective:						
Independent units	219.9	343.9[b]	72.0	422.0[b]	12.2[d]	31.4
Total	264.7[a]	1,119.2[#e]	81.6[c]	488.3[#e]	N.A.	37.7[#e]
All industry:						
Independent SOE and COE units	N.A.	420.9[e]	389.3*	1,416.7*	42.6	74.0*
Total	348.4[a]	7,371.8[#b]	423.7[a]	1,652.0[#b]	60.9[f]	97.3[#]

NOTE.—Except as noted, data were provided by the State Statistical Bureau; * indicates sum of state and collective components; # indicates data obtained by subtracting figures pertaining to village-level units from global totals; ? indicates an apparent inconsistency in our source materials.

[a] *Industry, 1988*, pp. 15, 25.

[b] *TJNJ 1989*, pp. 268–69, 271, 273, 275, 295.

[c] Calculated by applying the shares of state and collective industry in 1978 gross industrial output at 1970 prices to the current price total. Output shares are from *Industry, 1986*, p. 128.

[d] *TJNJ 1988*, pp. 163, 166.

[e] *Industry, 1989*, pp. 3, 353.

[f] *Industry, 1988*, p. 10; including village and subvillage units.

even more autonomy and flexibility. Their high birth and mortality rates clearly reflect changing market conditions as well as official policies.[3] Large numbers of small private enterprises (6.1 million at the end of 1988) and several thousand joint ventures (including 1,242 involving nonresident investors) round out the roster of Chinese industrial firms.[4] With the exception of the larger joint-venture firms, these units occupy the market-oriented extreme of China's industrial system.

Data availability confines our study to independent accounting units within the state and collective segments of industry (which includes mining and utilities as well as manufacturing) at or above the township level. We exclude industrial activities that are administratively situated within nonindustrial units, such as furniture-making shops maintained by universities, as well as private and joint-venture firms and all village-level industrial activity.

The implications of these limitations are demonstrated in table 1, which provides a brief quantitative description of Chinese industry in 1978 and 1988. The state and collective independent accounting units included in our analysis dominate industrial output; they account for 92% of industrial production in 1978 and 86% of total output (78% if village-level enterprise is added to the total) in 1988.[5]

Partial information on the composition of industrial output, shown in table 2, reveals similarities as well as differences in the composition of output in the two segments of industry. Machinery is uniformly larger than any other component, contributing about one-quarter of state and one-third of collective-sector output. Apparel and building materials occupy much larger positions in the collective sector than in state industry. Food processing and metallurgy contribute much more to the output total for state than for collective industry.

The data show distinct signs of structural convergence. Without exception, the share in collective industrial output for each branch shown in table 2 moves toward the corresponding branch share in the state-sector total. Table 2 also conceals important differences between state and collective activity within single branches of industry. In machinery, for example, large and complex items are made almost exclusively by state firms, while collective units tend to specialize in producing simple, standardized machines or components.

The data show much greater structural change in collective than in state industry, suggesting that aggregate production technology may be less stable for collective than for state industry. We will return to this issue in Section V.

III. Previous Work

In spite of two waves of industrial reform—the broadening of enterprise autonomy during 1979–83 and the expansion of product markets and price reforms beginning in 1984—the World Bank and other interested analysts speculated well into the 1980s that new policies had failed to end the long stagnation of productivity in China's state industry.[6] Using reconstructed factor input data and applying improved analytic methods, K. Chen et al. conclude that, after stagnating during 1957–78, multifactor productivity (capital and labor) in state industry grew at a rate of 4%–5% per annum during 1978–85.[7]

Subsequent papers by K.-T. Lau and J. C. Brada and by M. Beck and A. Bohnet use these revised data to estimate frontier production functions for the purpose of identifying sources of year-to-year productivity change. These authors confirm the broad pattern of productivity change reported by Chen et al.[8]

G. H. Jefferson uses 1984 cross-section data to examine the production technologies of state and collective industry.[9] He finds that the marginal returns to labor are considerably higher within the state sector, while returns to capital are substantially higher within the collective sector. In contrast to the time-series results in Chen et al.,

TABLE 2

BRANCH COMPOSITION OF STATE AND COLLECTIVE INDUSTRIAL OUTPUT, 1978 AND 1987 (Percentages)

	MACHINERY (1)	APPAREL AND LEATHER* (2)	CHEMICALS (3)	BUILDING MATERIALS (4)	TEXTILES (5)	FOOD PROCESSING† (6)	METALLURGY‡ (7)
State sector:							
1978	21.12	1.04	11.81	2.75	13.83	12.44	11.80
1988	27.36	.97	12.38	2.66	13.68	12.99	9.77
Collective sector:							
1978	36.07	11.28	10.94	8.37	7.90	2.96	1.97
1988	33.54	7.89	12.06	7.19	15.70	5.53	3.69

NOTE.—These data are based on output totals in 1980 prices for independent accounting units at and above the township (*xiang*) level. Enterprises supervised at or below the village level are excluded. Materials used by the State Statistical Bureau to compile these figures are based on a 15-branch classification for 1978 and a 40-branch system for 1987. The 1987 figures have been converted to the earlier accounting system using the concordance given in *Industry, 1988*, pp. 380–98.

* These are combined because there are no separate data for 1978.

† Including beverages and tobacco.

‡ Including mining of metallic minerals.

Jefferson's cross-section data offer strong evidence of increasing returns to scale in both state and collective industry.

R. H. McGuckin, S. V. Nguyen, J. R. Taylor, and C. A. Waite use data from China's 1985 industrial census to evaluate multifactor productivity for 39 branches of industry during 1980–85.[10] They conclude that multifactor productivity in the state sector declined during this period. This outcome, however, depends on the use of factor income shares to aggregate labor and capital inputs, a method that requires the improbable assumption of perfect competition in China's factor markets. Several Chinese authors have obtained a variety of results using similar methods.[11]

Jefferson investigates sources of productivity differences among 120 enterprises within China's iron and steel sector and the pace of productivity change within the iron and steel sector as a whole.[12] The results underscore the importance of price regimes, asset types and vintages, and scale economies in explaining productivity differences.

In one of several World Bank studies of the TVE sector, J. Svejnar finds that technical change within this sector occurred at a high average annual rate of 14.5% during 1978–86.[13] However, this result, like that of McGuckin et al., is sensitive to the weights used and may also reflect the impact of inflation.

All of these studies restrict their analysis to a net output framework that focuses on capital and labor but excludes materials inputs (including energy), which often constrain China's industrial production. None of these studies draws direct comparisons between the productivity performance of the state and collective sector over time. Previous work has not investigated whether returns to capital, labor, and materials between China's state and collective sectors have converged or diverged, a key issue in evaluating the success of China's urban reforms. The following analysis seeks to fill these gaps.

IV. Data Issues and Statistical Profile

Comparative analysis of productivity performance in state and collective industry requires constant price measures of gross industrial output value, fixed assets, and intermediate inputs (alternatively referred to as materials), along with physical measures of labor. Table 3 presents basic data from Chinese statistical sources covering gross and net output and capital and labor inputs for state and collective industry during 1979–88.[14]

The figures for employment (col. 8) and total fixed assets (cols. 4, 7) include nonindustrial resources used to provide housing, schools, health facilities, and other services for industrial workers and their families. In addition to these series, which resemble the data used in earlier productivity studies, we now have a series (OPF*) that includes only the original (gross) value of fixed assets used for industrial produc-

TABLE 3

Basic Statistics for State and Collective Industry, 1979–87

	DGV (1)	GV (2)	NV (3)	OF* (4)	CC (5)	OPF* (6)	NF* (7)	LAB[a] (8)
State:								
1979	359.11[b]	352.43	121.53	346.67	12.18	295.31	237.87	N.A.
1980	379.14[b]	376.16	131.91	373.01	13.71	311.62	252.80	31.78
1981	387.53	385.95	131.75	403.23	14.73	332.30	270.93	33.27
1982	414.58	413.32	137.29	437.54	15.94	360.73	291.40	34.55
1983	453.56	452.40	150.08	476.78	18.10	388.25	316.10	35.28
1984	497.01	505.42	172.10	516.00	20.85	419.33	339.55	35.73
1985	565.68	611.49	205.77	595.61	24.70	487.01	398.08	37.04
1986	616.69	688.82	220.73	678.55	28.73	546.17	450.93	38.85
1987	668.42	799.39	252.94	767.79	32.42	617.96	525.24	39.82
1988	748.03	994.67	306.30	879.52	37.94	712.67	604.04	41.33
Collective:								
1979	80.41[b]	77.95	27.03	33.71	2.22	29.31	25.25	N.A.
1980	96.10[b]	92.60	32.22	39.67	2.61	34.79	29.73	20.80
1981	105.44	101.63	34.26	46.30	3.03	40.52	34.58	21.97
1982	115.67	110.31	36.88	53.55	3.41	46.17	39.58	22.77
1983	131.34	124.80	41.53	61.12	3.87	52.30	44.71	23.48
1984	168.43	161.20	50.56	71.88	4.81	60.73	51.93	24.94
1985	217.53	217.09	67.94	88.86	5.72	75.44	65.14	26.99
1986	252.84	256.12	76.29	111.43	7.64	95.34	82.99	29.00
1987	299.22	314.35	89.40	137.19	8.75	115.26	101.66	29.98
1988	372.72	422.00	113.52	167.56	11.00	141.07	124.08	30.56

Note.—Data for cols. (1) through (8) were provided by the State Statistical Bureau.
[a] Millions of persons; all other data are in billions of yuan.
[b] Estimated by multiplying 1980 and 1979 values of 1970 constant price GVIO by the 1970/1980 constant price GVIO ratio calculated for 1981.

tion (*gongye schengchanyong;* col. 6). While this series excludes facilities linked with nonindustrial services, it represents an aggregation of investment goods of different vintages, each valued at original cost, that cannot provide a sound basis for estimating the growth of real capital stock. Measurement bias arising from Chinese accounting methods has become serious since 1980, as investment costs have risen steeply.[15] To address this shortcoming of the capital stock data, we have prepared a deflated net capital stock series using the method described in Appendix B. The adjusted series appears in column 2 of table 4.

Appendix B also lays out our method of constructing a time series of intermediate inputs in constant prices. The derived series (DINT) appears in table 4 (col. 4). Table 4 also presents the deflators that we use to obtain time-series data in real terms for gross output (DEFQ), new investment (DEFK), and materials purchases (DEFM).[16]

In table 5, we use the revised input data to compare the levels and relative changes in real output value per unit of labor, fixed capital, and materials in state and collective industry during 1980–88. These

TABLE 4

Adjusted Data and Critical Series

	DGV* (1)	DNPF† (2)	LAB‡ (3)	DINT§ (4)	DEFQ‖ (5)	DEFK# (6)	DEFM** (7)
State:							
1980	379.14	205.05	31.78	222.84	1.000	1.000	1.000
1981	387.53	211.20	33.27	229.69	1.004	1.059	1.007
1982	414.58	221.73	34.55	246.89	1.005	1.066	1.017
1983	453.56	233.25	35.28	266.25	1.005	1.151	1.030
1984	497.01	242.36	35.73	278.28	1.025	1.233	1.083
1985	565.68	262.89	37.04	307.05	1.090	1.320	1.199
1986	616.69	289.26	38.85	331.21	1.126	1.421	1.281
1987	669.42	311.74	39.82	349.15	1.205	1.508	1.424
1988	748.03	340.95	41.33	372.78	1.340	1.575	1.691
Collective:							
1980	96.10	23.54	20.80	56.47	1.000	1.000	1.000
1981	105.44	26.56	21.97	62.64	1.000	1.048	1.003
1982	115.67	29.21	22.77	67.98	.990	1.054	1.005
1983	131.34	31.54	23.48	76.33	.986	1.126	1.015
1984	168.43	34.22	24.94	91.58	.993	1.199	1.129
1985	217.53	39.28	26.99	113.76	1.036	1.284	1.236
1986	252.84	47.13	29.00	129.03	1.051	1.374	1.305
1987	299.22	55.24	29.98	146.36	1.090	1.451	1.447
1988	372.72	63.78	30.56	169.36	1.175	1.506	1.724

* Gross industrial output value: billions of yuan, 1980 prices.

† Net value of productive fixed assets (average of consecutive year-end figures): billions of yuan, 1980 prices.

‡ Total work force (average of consecutive year-end figures): millions of workers.

§ Intermediate inputs in constant 1980 prices.

‖ Product price deflators (1980 = 1.000).

Capital goods price deflator (1980 = 1.000).

** Price deflator for intermediate inputs (1980 = 1.000).

figures show labor productivity in the collective sector converging from below toward the level of state-sector labor productivity. The results exaggerate the degree of convergence because (i) the collective output figures may contain an upward bias, especially for 1984–88 (see Sec. VIII below), and (ii) removal of nonindustrial labor from the employment series would probably result in a larger increase in labor productivity for the state sector than for collective industry.[17]

Table 5 shows that capital productivity is higher in the collective than in the state sector. While output per unit of fixed assets in the state sector increased by 18.6% during 1980–88, the average productivity of capital rose much faster (43.1%) in collective industry, resulting in a growing gap between average output per unit of fixed assets in the two sectors.[18]

Average 1980 output per unit of materials was identical in state and collective industry. Both sectors improved their performance in this area, but partial productivity rose more rapidly in the collective

TABLE 5

COMPARATIVE MEASURES OF AVERAGE PRODUCTIVITY (Yuan of Nominal [GV] or Real [DGV] Output per Unit)

	SOE Labor	SOE Capital	SOE Materials	COE Labor	COE Capital	COE Materials
Nominal (GV; current prices):[a]						
1980	11,837	1.834	1.688	4,452	3.933	1.640
1981	11,601	1.726	1.669	4,626	3.651	1.618
1982	11,963	1.749	1.646	4,845	3.583	1.615
1983	12,823	1.685	1.650	5,315	3.514	1.611
1984	14,146	1.691	1.677	6,464	3.929	1.559
1985	16,509	1.762	1.662	8,043	4.304	1.544
1986	17,730	1.676	1.623	8,832	3.955	1.521
1987	20,075	1.700	1.608	10,485	3.922	1.484
1988	24,067	1.852	1.578	13,809	4.393	1.445
Growth rate (%)	8.87	.12	−.84	14.15	1.38	−1.58
Real (DGV; 1980 prices):[b]						
1980	11,930	1.849	1.701	4,620	4.082	1.702
1981	11,648	1.835	1.687	4,799	3.970	1.683
1982	11,999	1.870	1.679	5,080	3.961	1.702
1983	12,856	1.944	1.703	5,594	4.164	1.721
1984	13,910	2.051	1.786	6,753	4.922	1.839
1985	15,272	2.152	1.842	8,059	5.538	1.912
1986	15,874	2.132	1.862	8,719	5.365	1.959
1987	16,786	2.144	1.914	9,980	5.417	2.044
1988	18,099	2.194	2.007	12,196	5.843	2.201
Growth rate (%)	5.21	2.14	2.06	12.13	4.49	3.21

[a]Labor = GV/LAB; capital = GV/(DNPF × DEFK); materials = GV/(DINT × DEFM).
[b]Labor = DGV/LAB; capital = DGV/DNPF; materials = DGV/DINT.

(3.2% annual rate) than in the state (2.1%) sector, with the result that average collective output per unit of intermediate consumption was nearly 10% above the comparable figure for state enterprises in 1988.

In order to measure comparative rates of change in overall sectoral efficiency, it is necessary to obtain weights to combine independent measures of capital, labor, and material productivity. Also, since single-factor productivity measures are average rather than marginal measures, they cannot be used to compare the marginal revenue products of capital, labor, and materials between the state and collective sectors. To determine whether these factor returns are converging or diverging over time, we need output elasticities derived from production function estimates to rescale our measures of average productivity.

V. Production Function Estimates

In their investigation of the long-term productivity performance of state-owned industry, Chen et al. estimate weights for capital and labor from time-series data.[19] Unfortunately, we have no time series long enough to permit the estimation of a production function for collective industry. We therefore turn to cross-section data for 1984 and 1987. These data, taken from yearbooks of urban statistics, provide observations of output and input for state and collective industry for each of several hundred cities and counties for these 2 years.

Since our focus is on the contribution of labor, capital, and materials to output at the level of the state or collective sector, rather than the technological characteristics of the individual localities in the sample, we use the Cobb-Douglas function to estimate factor output elasticities that are assumed to be constant across all observations within each sector. Moreover, due to the extent of structural change within Chinese industry, particularly within the collective sector (table 2), rather than using a flexible functional form, we test the intertemporal stability of Cobb-Douglas estimates obtained from data at different points during the reform program. This strategy reflects our belief that changing factor output elasticities are likely to take the form of changes in curvature rather than movements along a stable production function. For both sectors, the function is specified as follows:

$$q_i = \alpha_O + \alpha_K k_i' + \alpha_L l_i + \alpha_M m_i + \epsilon_i, \qquad (1)$$

where i represents observations for industrial aggregates for a cross-section of urban areas (*shiqu*). The variables q, k', l, and m represent logarithms of average enterprise values within each urban area for gross output at 1980 prices, year-end value of net fixed assets, year-end employment, and annual consumption of intermediate inputs (which we convert to 1980 prices).[20] Finally, ϵ is a stochastic variable that is assumed to satisfy the classical assumptions of the basic regression model.

In order to adjust for differences in measured fixed assets arising from the recent inflation of capital goods prices, k', an efficiency-price adjusted measure of the capital stock, is expressed as

$$k_i' = k_i + \theta v_i, \quad (2)$$

where k and v are logarithms of average enterprise figures in various localities for the year-end value of fixed assets (OF*) and the ratio of the net (NF*) to original (OF*). Since the rate of price increase for investment goods has risen throughout the period covered in this study, v appears to be a suitable proxy for the investment goods price deflator. Unless the rising price of investment goods has been warranted by the rising technical efficiency of capital, estimates of θ will be negative. The interpretation of θ is further developed when the results are discussed at the end of this section.[21]

For estimation purposes, equation (2) is substituted into equation (1), which is then transformed into the following intensive form:

$$(q - l)_i = \alpha_o + \beta q_i + \alpha_k(k - l)_i + \alpha_m(m - l)_i + \alpha_v v_i + e_i, \quad (3)$$

where $\beta = (\sigma - 1)/\sigma$ and σ, the scale parameter, equals $\alpha_K + \alpha_L + \alpha_M$, $\alpha_k = \alpha_K/\sigma$, $\alpha_m = \alpha_M/\sigma$, $\alpha_l = 1 - \alpha_k - \alpha_m$, $\alpha_o = \alpha_O/\sigma$, $\alpha_v = \alpha_K\theta/\sigma$, and $e = \epsilon/\sigma$. Since the factor coefficients have been normalized to sum to unity, the elasticity estimates obtained from equation (3) are the appropriate weights to use for the calculation of total-factor productivity.

The intensive formulation shown in equation (3) is designed to minimize potential errors-in-variables problems. The first issue that invites this transformation arises from inconsistencies in the coverage of the data. In order to allow for estimates of enterprise-level economies of scale, equation (1) is formulated in terms of average input and output quantities per enterprise. Our input and output data cover independent accounting units in state and collective industry, but the data showing the number of enterprises include all units and therefore somewhat overstate the desired figure for independent accounting units. If, as in equation (3), we subtract from both sides of equation (1) the (logarithm of) average employment per enterprise, then the measures of labor, capital, and materials productivity are free from this source of measurement error. The direct effect of this inconsistency in coverage is limited to the scale variable, q_i, for which we can construct an instrument to correct for the estimation bias from the remaining measurement error.

The second reason for using the intensive form of equation (1) is to reduce the impact of the nonindustrial components included in the input data. Because these data include nonindustrial fixed assets and workers associated with the operation of housing, schools, health facilities, and other services that industrial enterprises supply to their employees, they are not true measures of industrial inputs.[22] However, using the capital-labor and the materials-labor ratios rather than the input levels can reduce the extent of measurement error and estimation bias. This is because the errors embedded in the observed values of capital, labor, and materials should be positively correlated, causing ratios of these variables to be measured with less error than either component of the ratio.

In principle, a set of instrumental variables could remedy the biases associated with the use of input data that include nonindustrial components and a measure of average enterprise size based upon a broader sample than the output data. Our data, however, are not adequate for this purpose. Instead, we use the intensive form of the production function and create an instrumental variable only for the scale variable, q, since q potentially suffers both from measurement error and simultaneity bias.[23]

We estimate equation (3) separately for state and collective industry, using a consistent sample of 293 observations drawn from cross-section data for 295 city/county units in 1984 and 382 units in 1987.[24] The year 1984 is an important break point from the perspective of institutional change; we anticipate that new policies implemented in 1984 may have altered patterns of productivity change. The last year for which we have the data needed to support our cross-section analysis is 1987.[25]

We estimate equation (3) using a novel frontier procedure that appears more appropriate for the task and the data than conventional frontier methods. In the present context, standard frontier approaches are not appropriate, since, for purposes of comparing sectors, we require descriptions of the technical properties of the sectoral aggregates for state and collective industry.[26] Since measurement error, the retention of extensive nonindustrial inputs, and administered prices may account for the apparent inefficiencies of the observations most "off" the production function, we choose to omit a large fraction of these observations. At the same time, because of measurement error and pricing practices that unduly inflate output values or limit the cost of inputs, we cannot rely on a few extreme observations to determine the frontier. By limiting the sample to approximately one-third of the more efficient observations, while purging the sample of a small number of observations at the frontier (less than 10) that appear to affect the stability of the estimates, our quasi-production function approach obtains estimates from a part of the sample that is relatively efficient in the technical and institutional sense and yet more broadly representa-

TABLE 6

ESTIMATION RESULTS

	STATE	COLLECTIVE	
	1984–87	1984	1987
Coefficients for equation (3):			
Constant (α_o) (1984)	1.228	1.716	N.A.
	(89.885)	(27.536)	
Constant (α_1) (1987)	1.513	N.A.	1.690
	(11.192)		(21.629)
Scale (β_o) (1984)	.066	.046	N.A.
	(8.077)	(13.908)	
Scale (β_1) (1987)	.029	N.A.	.020
	(1.582)		(3.813)
Capital (α_k)	.205	.165	.134
	(17.791)	(22.462)	(11.087)
Labor (α_l)	.120	.158	.117
	(7.232)	(18.952)	(11.426)
Intermediate inputs (α_m)	.675	.677	.749
	(76.333)	(123.443)	(62.930)
Vintage (α_v) (1984)	.171	.035	N.A.
	(3.114)	(1.427)	
Vintage ($\alpha_v{}^1$) (1987)	−.085	N.A.	−.209
	(−1.346)		(−5.522)
R^2	.985	.997	.996
Stability test (1984–87)	$F(2,180) = 2.35$ (3.04)	$F(2,171) = 16.97$ (3.04)	
Range of stability:			
1984	74 (96) 131	45 (90) 111	
1987	62 (94) 113		50 (91) 122

	STATE		COLLECTIVE	
	1984	1987	1984	1987
Scale parameter (σ); factor output elasticities [eq. (1)]:				
$\sigma = 1/(1 - \beta)$	1.071	1.030	1.039	1.026
$\alpha_I = \sigma \times \sigma_i$:				
$\alpha_K =$	.220	.211	.171	.137
$\alpha_L =$	.129	.124	.164	.120
$\alpha_M =$	.723	.695	.703	.768

tive of the original sample than just a small fraction of observations at the frontier. In addition, our method clearly specifies both the cross-sectional and intertemporal stability properties of the estimates, which allows the reader to form independent judgments about their quality.[27]

The results reported in table 6 show that the estimated factor share parameters (α_k and α_m) remain constant between 1984 and 1987 for the state sector but not for the collective sector. The hypothesis of constant returns to scale is rejected for both sectors. For the state sector, the scale parameter (σ) is 1.071 for 1984 and 1.030 for 1987, while for the collective sector σ is 1.048 for 1984 and 1.020 for 1987.[28] We can suggest two possible explanations for the larger estimate for scale economies in state industry. Processing industries like petroleum refining that often exhibit scale economies are concentrated within the state sector. Furthermore, the state sector is, in general, more able to support small loss-making enterprises than the less sheltered collective sector.[29]

Estimates of the vintage coefficients (table 6) indicate changing efficiency-price ratios of investment goods between the two sectors and also between the earlier (1980–84) and later (1985–88) reform periods. Since estimates of $\alpha_v > 0$ indicate that the efficiency of new vintages of investment are rising relative to their cost, positive estimates of the vintage parameter suggest that, particularly for state-sector investment, during the early 1980s, the quality of investment goods rose more rapidly than their cost. By 1987, however, the estimates of α_v turn negative, indicating that investment goods prices appear to have outstripped quality improvements after 1984.

Table 6 also indicates the range of stability for each set of estimates. Taking the collective sector in 1984 as an example, we see that the estimates of β, α_k, and α_m obtained from the third of the sample closest to the frontier (i.e., observations 1–90) were stable over the range 1–45 (the upper bound) to 1–111 (the lower bound).

VI. Sources of Growth and Productivity Change

Using the adjusted input and output data (table 4) and the normalized estimates of the output elasticities for capital, labor, and materials (table 6), we can calculate comparative rates of sectoral productivity change and describe the sources of sectoral growth. We calculate the rate of growth of total-factor productivity using the following expression:

$$\text{tfp} = \text{dgv} - \alpha_k \text{dnpf} - \alpha_l \text{lab} - \alpha_m \text{dint}, \tag{4}$$

where tfp is the exponential growth rate of total-factor productivity and the right-hand variables are exponential growth rates for DGV, DNPF, LAB, and DINT (table 4) over the relevant period. We use 1984 elasticities for the years 1980–84 and 1987 elasticities for 1987–88 and derive elasticities for 1985 and 1986 by linear interpolation between the values for 1984 and 1987.

Table 7, which contains the outcome of these calculations, reveals that the major impetus to growth within both sectors came from rapid expansion of material inputs combined with large values of the output elasticity for materials. Productivity growth made the second-largest contribution to growth in both sectors, with expansion of fixed assets and labor accounting for positive but small shares of incremental output.[30] Rising material inputs accounted for slightly more than half of

TABLE 7

Contributions to Annual Rates of Output Growth
(Exponential Growth Rates in Percent per Annum)

Period	dgv	= $\alpha_k$dnpf	+ $\alpha_l$lab	+ $\alpha_m$dint	+ tfp	(tfp = se + tech) se*	tech**
State:							
1980–88	8.49	1.45 (6.36)	.34 (3.28)	4.31 (6.43)	2.40	.36	2.04
1980–84	6.77	.95 (4.18)	.30 (2.93)	3.72 (5.55)	1.80	.35	1.45
1984–88	10.22	1.95 (8.53)	.37 (3.64)	4.90 (7.31)	3.01	.37	2.64
Collective:							
1980–88	16.94	1.96 (12.46)	.66 (4.81)	9.70 (13.73)	4.63	.44	4.19
1980–84	14.03	1.67 (9.35)	.61 (4.54)	8.30 (12.09)	3.45	.35	3.09
1984–88	19.86	2.45 (15.57)	.70 (5.08)	10.85 (15.37)	5.86	.59	5.27

Note.—Figures in parentheses are exponential rates of growth of factor inputs.
* se = βq, where se is the rate of change in enterprise scale and q is calculated using DGV (table 4), number of enterprises (n. 31), and β (table 6).
** Calculated as tfp − se.

both state and collective output growth during 1980–88. Substitution of materials for capital and labor during this period raised the productivity of labor and capital among both state and collective producers.

Within both sectors, the growth of total-factor productivity also contributed to the growth of output, accounting for slightly more than one-fourth of increased production. Productivity growth was higher in collective (4.63% annual increase) than in state (2.40% annual growth) industry. Both segments show a pattern of accelerating growth of total-factor productivity during the 1980s.

Total-factor productivity growth can be decomposed into technical change and changes in enterprise scale. Productivity increases resulting from the growth of enterprise scale are calculated as $\beta(\text{dgv} - n)$, where β emerges from the estimation of equation (3) (see table 6) and dgv and n are exponential rates of growth for deflated output (table 4) and the number of enterprises.[31] The last two columns of table 7 show the results of this decomposition. Although scale economies have made small but consistent contributions to growth and productivity change, the increase in total-factor productivity is primarily attributable to "technical change," that is, increases in output per unit of combined factor input, holding enterprise scale constant.

VII. The Level and Dispersion of Factor Returns

In a market economy, profit-seeking behavior on the part of sellers and buyers tends to erode intersectoral and interregional differences in returns to labor, capital, or materials. Divergent returns signal the presence of opportunities to increase output without extra resources or new technologies. In a planned economy, pressure to improve financial performance is conspicuously absent. Long-term subsidy arrangements often create and maintain widely divergent factor returns. Furthermore, the constant reshuffling of resources required to eliminate differences in factor returns may be difficult or even illegal. As a result, a planned economy, unlike a market system, generates little or no momentum toward the convergence of returns to labor, capital, or materials in different enterprises, trades, or regions.

This sharp distinction between the outcome of plan and market systems opens the way to a quantitative evaluation of the reform process now under way in China and other socialist economies. If reform policies expand the role of market forces, competition should begin to erode long-standing divergences in factor returns. Tests for the convergence of returns thus offer a sensitive gauge of progress toward China's goal of injecting market forces into the plan system. Although this is not attempted here, it should be possible to measure the contribution of this convergence process to raising efficiency, as resources gravitate from lower- to higher-productivity activities.[32]

To this point, we measure productivity exclusively in real terms. But the growth, convergence, and divergence of household living standards and enterprise profits in China, as in all countries, depend on changes in nominal returns. To calculate nominal returns to capital, labor, and materials for the state and collective sectors, we use the following expressions:[33]

$$\begin{aligned} \mathrm{MRP_{Lt}} &= \alpha_L(\mathrm{GV}_t/\mathrm{LAB}_t), \\ \mathrm{MRP_{Kt}} &= \alpha_K(\mathrm{GV}_t)/(\mathrm{DNPF}_t \times \mathrm{DEFK}_t), \text{ and} \\ \mathrm{MRP_{Mt}} &= \alpha_M(\mathrm{GV}_t)/(\mathrm{GV}_t - \mathrm{NV}_t - \mathrm{CC}_t - \mathrm{MRF}_t), \end{aligned} \tag{5}$$

where GV, NV, and CC are from table 3; DNPF, LAB, and DEFK are from table 4; and the output elasticities α_L, α_K, and α_M appear in table 6.[34]

The results of these calculations,[35] shown in table 8, suggest modest change during the 1980s in the direction of market-like outcomes across the state and collective segments of industry, which is the largest sector of China's economy.[36] Even though labor markets remain relatively undeveloped—only 1.3% of 99.8 million regular state-sector workers left their positions in 1988[37]—the data in table 8 reveal a slow but steady movement toward convergence of returns to labor across state and collective industry during 1980–84. The initially low marginal returns to labor in collective industry, expressed as a percentage of comparable figures for the state sector, increase monotonically

TABLE 8

Nominal Marginal Revenue Products: Labor, Capital, Materials

	MRP_L		MRP_K		MRP_M	
	Level	Index	Level	Index	Level	Index
State:						
1980	1,520.75	100.00	.403	100.00	1.220	100.00
1981	1,490.44	98.01	.379	94.04	1.206	98.85
1982	1,536.99	101.07	.384	95.29	1.190	97.54
1983	1,647.53	108.34	.370	91.81	1.192	97.70
1984	1,817.42	119.51	.371	92.06	1.212	99.34
1985	2,093.43	137.66	.382	94.79	1.185	97.13
1986	2,219.35	145.94	.358	88.83	1.143	93.69
1987	2,480.96	163.14	.359	89.08	1.118	91.64
1988	2,974.24	195.58	.391	97.02	1.097	89.92
Growth rate (%)	8.38		−.37		−1.33	
	MRP_L		MRP_K		MRP_M	
	Level	Index*	Level	Index*	Level	Index*
Collective:						
1980	737.29	48.48	.680	168.73	1.164	95.41
1981	766.16	51.40	.632	166.75	1.148	95.19
1982	802.34	52.20	.620	161.46	1.146	96.30
1983	880.30	53.43	.608	164.32	1.143	95.89
1984	1,070.48	58.90	.679	183.02	1.106	91.25
1985	1,205.97	57.61	.692	181.15	1.125	94.94
1986	1,188.05	53.53	.588	164.25	1.135	99.30
1987	1,251.82	50.46	.536	149.30	1.134	101.43
1988	1,648.60	55.43	.601	153.71	1.105	100.73
Growth rate (%)	10.06		−1.55		−.65	

* Relative magnitude (comparable state sector figure = 100.0).

from 48% in 1980 to 59% in 1984. This movement in the direction of convergence did not, however, continue after 1984.

In the case of fixed capital, we again find that the initial gap separating marginal returns in state and collective industry declines during the period of our study. Relative marginal returns to fixed assets in collective industry, 69% above corresponding state industry figures in 1980, decline to a level of 54% higher than comparable state industry results for 1988. Here, however, movement in the direction of convergence is concentrated within the last 3 years of the analysis.

These outcomes reflect several distinct influences. The narrowing of intersectoral returns to labor parallels the convergent trend to real output per worker (table 5), in which the figure for collective industry rose from 39% to 67% of state-sector results between 1980 and 1988. In calculating marginal returns according to equation (5), the large differences between the average 1980 productivity of labor and capital in state and collective industry are narrowed by the relative size of their output elasticities (table 6). Moreover, with the exception of labor, changes in the relative magnitudes of these elasticities between 1984 and 1987 (table 6) contribute to the convergence of nominal marginal returns.

These modest shifts toward intersectoral convergence of returns to capital and labor are surprising because China's capital markets appear to be strongly segmented, while labor markets appear to be among the less developed aspects of China's nascent market network. Industrial reform has, however, brought a new system of profit retention and encouraged the development of formal and informal sources of investment capital outside the state planning system. These changes have allowed collective firms and small state enterprises to augment their stocks of capital rapidly despite their limited access to government funds. This process has narrowed differences between the capital intensity of small and large enterprises and contributed to the convergence of intersectoral factor returns.

Marginal returns to materials, also shown in table 8, display virtually full convergence throughout the period of analysis. The gap separating returns to intermediate inputs in state and collective industry exceeds 5% in only 1 of 8 years and is less than 2% during each of the final 3 years of our analysis. This unexpected result, which has survived numerous revisions of our data and analysis, flies in the face of conventional descriptions of China's prereform economy as one in which most intermediate inputs were distributed by bureaucratic fiat, an arrangement that, as noted above, generates little pressure toward equalization of marginal factor returns. We cannot explain this result, which must stand as a challenge to future researchers.

VIII. Conclusions, Qualifications, and Opportunities for Future Research

Previous analyses of Chinese industrial productivity have studied only the state sector and employed a limited framework in which labor and capital produce net output. In reality, coal and grain are required to manufacture coke and beer. The inclusion of materials in the analysis of production is particularly worthwhile in China, where their share of industrial costs is exceptionally high. The addition of collective industry, a large and dynamic segment of China's economy that in 1988 produced a higher level of gross output than China's entire agricultural sector, is equally significant.[38]

Productivity comparisons for independent accounting units within state and collective industry during 1980–88 based on factor weights obtained from a three-input Cobb-Douglas cross-section production function estimated from data for 1984 and 1987 lead to the following results:

1. The overall trend of productivity change in Chinese industry during the 1980s is upward, although the growth of productivity, amounting to 2.4% per annum for state industry and 4.6% for the collective sector, falls considerably below the range of 4.8%–5.9% obtained in an earlier study covering state industry during 1978–85.[39]

2. The data suggest a substantial acceleration of productivity growth during the 1980s.

3. The growth of material inputs accounts for roughly one-half of total output growth, with lesser contributions coming from productivity, capital, and labor.

4. Differential growth of the collective sector relative to the state sector is due principally to more rapid expansion of material inputs, followed by the contributions of productivity change, capital, and labor, all of which grew faster in collective than in state industry.

5. If productivity growth is divided into two components representing technical change and scale economies, the contribution of the former component is far larger than the latter.

6. Even so, and notwithstanding the proliferation of small enterprises, we find positive scale effects in both state and collective industry, although our analysis cannot evaluate the efficiency consequences of the changing size distribution of industrial firms.

7. Comparison of nominal marginal factor returns across state and collective industry reveals modest shifts toward convergence of returns during the early (labor) or later (capital) years of the 1980s. We were surprised to find virtual identity of marginal returns to materials across state and collective industry in nearly every year. The results for labor and capital suggest modest progress toward the reform objective of injecting market-like outcomes into China's industrial economy.

Our study draws on a wide variety of Chinese data, including some that have yet to receive careful scrutiny from Chinese or outside researchers. We are particularly concerned about three areas: industrial price trends, industrial output indicators, and equipment deflators, where the possibility of measurement error seems considerable.

Chinese markets for industrial goods remain heavily regulated. Sellers encounter price limits, restrictions on the location of sales activity, and moral suasion, all intended to limit price increases.[40] These measures, aimed chiefly at large SOEs, create a strong presumption that the rate of industrial price increase is higher in the collective than in the state sector. Yet the price indexes derived from statistics of industrial output value at current and constant prices consistently show the opposite tendency (table 4). Published reports[41] and interview data indicating that newly established collective units sometimes substitute current for 1980 prices in calculating real output growth suggest that the output price indexes (DEFQ) in table 4 may contain distortions that have the effect of exaggerating the relative productivity performance of collective industry. Finally, product innovation, which sometimes leads to the use of current prices to calculate deflated output totals, may inject an upward bias into estimates of output growth in both state and collective industry.[42]

Even if our price indexes for industrial products are satisfactory, it is still possible that measures of real output (DGV) may suffer from upward bias.[43] If, as appears likely, the expansion of small-scale industry and the proliferation of markets for components and intermediate goods has encouraged a reduction in the average degree of vertical integration, the gross output measure used by Chinese statisticians may overstate the expansion of real output.

It is essential to recognize that the productivity consequences of measurement errors in output statistics are not easy to predict. Since the products of one industry often become intermediate inputs for another, revision of the output totals affects both the numerator and denominator of many productivity ratios. As an example of counterintuitive results, we may observe that a reduction in real output growth to correct innovation bias concentrated in the machinery industry might raise the measured productivity of capital.

Deflators for industrial fixed assets are based on data for construction costs and machinery prices. Our price index for machinery comes from the ratio between annual machinery output valued at current and constant prices (GV/DGV). Interviews conducted by ourselves and by Barry Naughton, as well as Jefferson's estimates concerning the bias of output growth within the machine-building industry, all indicate that machinery prices have outpaced the small increases obtained from ratios of GV/DGV, in which case the equipment component of our fixed asset deflator (DEFK) is flawed.

Our study directs attention to several opportunities for further research. We need to understand the magnitude and consequences of possible sources of measurement error. Not only our own results but assertions about the dynamism of collective industry and even estimates of national product growth during the past decade depend critically on the validity of the data underlying this study.

Our preliminary effort to study changes in marginal factor returns across two segments of industry shows the importance of working toward a more general framework for identifying the sources of convergence (or divergence) of factor returns, including changes in relative prices, factor deepening, technical change, and scale economies. This type of analysis could be used to examine progress toward market-like outcomes across sectors and over time, not only in China's economy but under any circumstances of economic disequilibrium.

Appendix A
List of Variables

We use the following conventions throughout this article:

1. The letter *D* is used as a prefix to indicate variables expressed in terms of 1980 prices.

2. For time-series data, capital letters indicate annual observations; lowercase letters indicate exponential growth rates expressed in percentage terms.

3. Year-end values of stock variables (employment, fixed assets) are marked with an asterisk; other data represent annual figures calculated as arithmetic averages of consecutive year-end totals. Thus LAB*, LAB, and lab refer respectively to year-end employment, average annual employment, and the exponential growth rate of average annual employment.

4. Variable names:

α_O	= Technology parameter
α_o	= α_O/σ
α_K; α_L; α_M	= Output elasticities for capital, labor, and materials
α_k; α_l; α_m	= Normalized elasticities for capital, labor, and materials: $\alpha_i = \alpha_I/(\alpha_K + \alpha_L + \alpha_M)$
α_v	= Coefficient for vintage term in equation (3)
β	= Coefficient for equation (3) related to scale parameter
CC	= Annual fund accumulated for capital consumption
DEFE	= Deflator for equipment costs
DEFK	= Deflator for fixed assets (including both equipment and structures)
DEFM	= Deflator for intermediate inputs
DEFQ	= Deflator for industrial output
δ	= Ratio of annual capital consumption (CC) to year-end fixed assets (OF*)
DGI	= Deflated value of annual gross increment to fixed assets used for industrial production
e	= Error term in equation (3)
ϵ	= Error term in equation (1)
GV	= Gross value of industrial output
Γ_i	= Shares of subsectors in annual equipment output; used to calculate DEFE
INT	= Value of intermediate input purchases
k	= Logarithm of average value of fixed assets per enterprise in cross-section analysis (eq. [2])
k'	= Efficiency-price adjusted measure of the logarithm of average year-end original fixed assets per enterprise in the *i*th locality, as defined in equation (2)
l	= Logarithm of average employment per enterprise in cross-section analysis (eq. [1])
LAB	= Annual average employment
m	= Logarithm of average purchase of intermediate inputs per enterprise in cross-section analysis (eq. [1])
MRF	= Annual fund accumulated for major repairs

MRP_K; MRP_L; MRP_M	=	Nominal value of marginal revenue product for capital, labor, and materials (eq. [5])
n	=	Exponential growth rate for the number of enterprises
NF	=	Net (of accumulated depreciation allowances) value of fixed assets, including assets not directly used for industrial production
NPF	=	Net value of fixed asssets used for industrial production
NV	=	Net value of industrial output
OF	=	Original cost of fixed assets, including assets not directly used for industrial production
OPF	=	Original cost of fixed assets used for industrial production
q	=	Logarithm of average gross output (GV) per enterprise in cross-section analysis (eq. [1])
S	=	Annual value of fixed assets scrapped (assumed to be zero)
se	=	Exponential rate of output growth arising from scale economies
σ	=	Scale parameter in cross-section analysis (see eq. [3])
tech	=	Exponential rate of technical change, net of scale effects
tfp	=	Exponential growth rate for total factor productivity
θ	=	Parameter reflecting the relationship between changes in the cost of fixed assets and their productive efficiency (eq. [2])
v	=	Vintage parameter: ratio of year-end figures for net value and original value of fixed assets (eq. [2])
τ	=	Estimated ratio of major repair fund to OF*

Appendix B
Data

This appendix summarizes the derivation of important time series. Full details appear in an annex that is available from the authors.

A. Real Stock of Fixed Capital Used for Industrial Production

The deflated net value of productive (*shengchanyong*) net fixed assets (DNPF) takes 1980 as the price base. We assume that changes in investment goods prices were negligible prior to 1980. This enables us to use undeflated year-end capital stock figures for 1979 as the starting point for the new series of deflated fixed assets. Subsequent figures are computed by adding deflated gross investment in fixed assets used for industrial production (DGI), net of deflated depreciation (DCC), and net scrap (S) to the initial figure. The average deflated net stock of productive fixed assets (DNPF) is the arithmetic average of consecutive year-end figures.

$$\mathrm{DNPF}_t = 0.5 \times (\mathrm{DNPF}^*_{t-1} + \mathrm{DNPF}^*_t), \qquad t = 1980\text{–}88 \tag{A1}$$

where

$$\mathrm{DNPF}^*_t = \mathrm{DNPF}^*_{t-1} + \sum_t (\mathrm{DGI}_t - \mathrm{DCC}_t - S_t). \tag{A2}$$

We obtain the 1979 year-end net value of productive fixed assets (which is assumed equal to the deflated net value of productive fixed assets at the end of 1979) by converting the net value of 1979 year-end total fixed assets using the ratio of productive to total fixed assets valued at original cost:

$$\mathrm{NPF}^*_{79} = \mathrm{DNPF}^*_{79} = \mathrm{NF}^*_{79} \times (\mathrm{OPF}^*/\mathrm{OF}^*)_{79}. \quad \text{(A3)}$$

We compute annual increments to the stock of fixed assets used for industrial production as follows:

$$\mathrm{DGI}_t = (\mathrm{OPF}^*_t - \mathrm{OPF}^*_{t-1})/\mathrm{DEFK}_t, \quad \text{(A4)}$$

where DEFK is the investment goods deflator constructed according to the procedure described below. We compute deflated depreciation (DCC) as follows:

$$\mathrm{DCC}_t = \delta_t \times \mathrm{DOPF}^*_t, \quad \text{(A5)}$$

where

$$\delta_t = \mathrm{CC}_t/\mathrm{OF}^*_t \quad \text{(A6)}$$

and

$$\mathrm{DOPF}^*_t = \mathrm{OPF}^*_{79} + \sum_t (\mathrm{DGI}_t - S_t) \quad \text{(A7)}$$

and where OPF^*_{79} is a year-end figure for 1979. We have found no data related to scrapping of fixed assets. We therefore assume there is no scrapping of productive capital (S):

$$S_t = 0 \text{ by assumption.} \quad \text{(A8)}$$

Reported series include original and net valuations of total year-end fixed assets (OF*, NF*) and original value of productive (*Gongye shengchan yong*, i.e., "used for industrial production") fixed assets (OPF*). The total depreciation fund (CC) is also available. This enables us to calculate the annual depreciation rate $\delta = \mathrm{cc}/\mathrm{OF}^*$, which we assume to be constant across productive and nonproductive capital.

Conversion of nominal investment totals to 1980 prices involves separate deflators for structures and equipment. Our deflator for structures is an index of annual construction costs per square meter of factory buildings.[44] For equipment, we construct implicit price deflators using annual SSB data for various industrial equipment types and aggregating in the following way:

$$\mathrm{DEFE}_t = \exp\left\{\sum_i [\Gamma_{it} \times \ln(\mathrm{GV}/\mathrm{DGV})_{it}]\right\}, \quad \text{(A9)}$$

where GV represents the nominal gross output value for equipment of type *i* in the year for which the deflator is being constructed and DGV represents the production value of the same equipment type in the same year valued in constant 1980 prices. The parameter Γ_{it} represents the share of equipment type *i* in the total nominal production value of industrial equipment in that year.

Although the same structure and equipment deflators are used for the state and collective sectors, these are combined, using different weights. During 1983–85, SSB data show that equipment costs accounted for a stable share of approximately 59% of investment outlays in the state sector of industry, implying a share of 41% for construction costs. For the state sector, we use these weights to calculate DEFK, the investment goods deflator, as a geometric mean of the separate equipment and structure deflators. For the collective sector, we perform a similar calculation based on assumed weights of 0.65 for equipment and 0.35 for structures.

B. Intermediate Inputs

We derive series for the nominal value of intermediate inputs (INT) from the following accounting identity:

$$GV_t \equiv NV_t + INT_t + CC_t + MRF_t, \tag{A10}$$

where GV, NV, and CC are defined in Section A above. The variable INT represents intermediate inputs (materials and energy) and MRF represents the major repair fund. For the state sector, we have annual data for MRF. For the collective sector, fragmentary data from a 1988 enterprise survey indicate that some collective enterprises accumulate major repair funds amounting to almost exactly one-half of annual depreciation figures. We therefore assume that annual accumulation of major repair funds for COE firms is one-half of annual depreciation funds.

A separate annex, available from the authors on request, provides a detailed explanation of the deflation of nominal figures for consumption of intermediate inputs. Our procedure includes separate annual calculations for state and collective industry of the following: (*a*) share of materials obtained through plan procurement and market purchase; (*b*) increase in exfactory prices of material inputs (this analysis uses input-output tables for 1981 and 1983); (*c*) extra markup paid for inputs purchased through markets. These calculations lead to the series of deflated material inputs (DINT) and to the material price deflator (DEFM) shown in table 4.

Notes

* We acknowledge support from the National Program for Advanced Study and Research in China, the National Science Foundation, the Henry Luce Foundation, the Joint Committee on Chinese Studies of the American Council of Learned Societies and the Social Science Research Council, the Institute of Quantitative and Technical Economics, and the Brandeis University Mazer Fund. This study has benefited from the research assistance of Wenyi Xu and the helpful comments of Bela Balassa, Robert M. Field, Nicholas Lardy, Li Liu, Guonan Ma, Barry Naughton, Louis Putterman, Robert Ross, Jan Svejnar, Hongchang Wang, Christine Wong, Geng Xiao, two review-

ers, and the staff of the Industry and Communication Division of the State Statistical Bureau (hereafter and in text, cited as SSB).

1. *Zhongguo tongji nianjian 1989* (China statistics yearbook, 1989) (Beijing: China Statistical Publishing House, 1989), p. 264. Annual volumes in this series are abbreviated below as *TJNJ*.

2. Kuan Chen, Gary H. Jefferson, Thomas G. Rawski, Hongchang Wang, and Yuxin Zheng, "Productivity Change in Chinese Industry: 1953–1985," *Journal of Comparative Economics* 12 (1988): 570–91.

3. *Renmin ribao* (People's daily, Beijing) (November 9, 1987) reports a total of approximately 700,000 bankruptcies in the TVE sector, apparently for 1986 alone.

4. For data on TVEs, see *Xiangzhen qiye tongji ziliao (1978–1986)* (Statistical materials on township and village enterprises, 1978–1986) (Beijing: Ministry of Agriculture, 1986); *Xiangzhen qiye tongji zhaiyao 1987* (Statistical survey of township and village enterprises, 1987) (Beijing: Ministry of Agriculture, 1987); and *Xiangzhen qiye tongji zhaiyao 1988* (Statistical survey of township and village enterprises, 1988) (Beijing: Ministry of Agriculture, 1988). Data on private and joint venture firms are from *Zhongguo gongye jingji tongji nianjian 1989* (Statistical yearbook of China's industrial economy, 1989) (Beijing: China Statistical Publishing House, 1989), p. 3. Annual volumes in this series are cited below and in text as *Industry*.

5. Coverage of industrial units, however, declines from over three-fourths in 1978 to less than 6% in 1988. This reflects the recent surge in enterprise formation in the private sector as well as the transfer of many rural enterprises from agriculture to industry within China's system of economic accounts. On the latter point, see Robert M. Field, "Trends in the Value of Agricultural Output," *China Quarterly* 116 (1988): 584–85.

6. World Bank, *China: Long-Term Development Issues and Options* (Baltimore: Johns Hopkins University Press, 1985), p. 111; Thomas G. Rawski, "Productivity Change in Chinese Industry: Problems of Measurement" (University of Pittsburgh, 1986, typescript); Gene Tidrick, "Productivity Growth and Technological Change in Chinese Industry," World Bank Staff Working Paper 761 (Washington, D.C., 1986), p. 4; and Nicholas R. Lardy, "Technical Change and Economic Reform in China: A Tale of Two Sectors" (University of Washington, 1987, typescript).

7. Kuan Chen, Gary H. Jefferson, Thomas G. Rawski, Hongchang Wang, and Yuxin Zheng, "New Estimates of Fixed Investment and Capital Stock for Chinese State Industry," *China Quarterly* 114 (1988): 243–66, and "Productivity Change in Chinese Industry."

8. Kam-Tim Lau and Josef C. Brada, "Technological Progress and Technical Efficiency in Chinese Industrial Growth: A Frontier Production Function Approach," *China Economic Review* 1, no. 2 (1990): 113–24; Martin Beck and Armin Bohnet, "Productivity Change in Chinese Industry: 1953–1985, Some Further Estimations" (Giessen, 1989, mimeographed).

9. Gary H. Jefferson, "Potential Sources of Productivity Growth within Chinese Industry," *World Development* 17, no. 1 (1989): 45–57.

10. Robert H. McGuckin, Sang V. Nguyen, Jeffrey R. Taylor, and Charles A. Waite, "Multifactor Productivity in Chinese Industry" (Washington, D.C., 1989, mimeographed).

11. Shi Qingqi, Tai Baoting, and Chen Jian, *Jishu jinbu yu jingji zengzhang* (Technical progress and economic growth) (Beijing: Kexue jishu wenxian chubanshe, 1985); Wang Zhiye, ed., *Jishu jinbu de pingjia lilun yu shijian* (Theory and practice of evaluating technical progress) (Beijing: Kexue jishu wenxian chubanshe, 1986); Zhao Huachuan and Guo Jilian, "Overall Evalua-

tion and Policy toward Scientific and Technological Progress in Chinese Industry," *Gongye jingji guanli congkan* 7 (1989): 8–14.

12. Gary H. Jefferson, "China's Iron and Steel Industry: Sources of Enterprise Efficiency and the Impact of Reform," *Journal of Development Economics* 33 (1990): 329–55.

13. Jan Svejnar, "Productive Efficiency and Employment," in *China's Rural Industry: Structure, Development, and Reform,* ed. William A. Byrd and Lin Qingsong (Oxford: Oxford University Press, 1990), p. 249.

14. A list of variables, with definitions, appears at the end of the article. We adopt several conventions for labeling time series data. Uppercase letters indicate absolute amounts; lowercase letters indicate exponential growth rates. Value totals reflect current prices unless preceded by the letter *D,* which indicates values converted to 1980 prices. Stock variables (capital, labor) refer to annual averages unless marked with an asterisk (*), which indicates year-end totals.

15. For elaboration on this point and its analysis of implications for productivity analysis, see Rawski, "Productivity Change in Chinese Industry" (n. 6 above); and Chen et al., "New Estimates of Fixed Investment and Capital Stock for Chinese State Industry" (n. 7 above).

16. An annex giving further detail on the derivation of these and other data items is available from the authors.

17. The relative importance of nonindustrial labor in state enterprises can be seen from 1985 census data showing that 70,342 state firms reported 15.0% of their workers in the "service" (*fuwu*) and "other" (*qita*) categories, which appear to consist mainly of personnel with nonindustrial duties, while a small group of unusually large collective firms classified only 11.4% of their workers as belonging to these categories. See SSB, *Zhonghua renmin gongheguo 1985 nian gongye pucha ziliao* (People's Republic of China industrial census materials, 1985) (Beijing: China Statistical Publishing House, 1987), 1:254–55; and *TJNJ 1987* (n. 1 above), pp. 492–93.

18. Average output per unit of fixed assets calculated from unrevised data (DGV/OPF*) declined by 13.7% (state) and by 3.7% (collective) during 1980–88. This illustrates the danger of mating standard productivity calculations without considering the special features of Chinese economic statistics.

19. Chen et al., "Productivity Change in Chinese Industry" (n. 2 above).

20. The intermediate input series is derived from the identity:

$$\mathrm{DINT}_i \equiv (1/\mathrm{DEFM}_i)\,[\mathrm{GV}_i - \mathrm{NV}_i\,(\delta + \tau)\mathrm{OF}_i^*],$$

where GV and NV represent the gross and net value of output in nominal terms, OF* represents year-end fixed assets valued at original cost, δ is the nationwide average rate of depreciation, and τ is an estimate of the ratio of the major repair fund to OF*. The depreciation rate, δ, is derived from annual values of depreciation allowances (cc) and fixed assets (OF*) shown in table 3. The parameter τ emerges from extensive major repair fund data for the state sector and from limited survey information for collective enterprises. Since the cross-section data provide nothing that can be used to construct separate materials price deflators for each city, we define $\mathrm{DEFM}_i = \mathrm{DEFQ}_i$ (DEFM/DEFQ), where the DEFQ_i are local gross output price deflators ($\mathrm{GV}_i/\mathrm{DGV}_i$) and DEFM and DEFQ are the nationwide gross output and material input price deflators shown in table 4.

21. G. Jefferson ("China's Iron and Steel Industry" [n. 12 above]) develops an earlier application using the vintage structure of capital as a proxy for changes in capital's efficiency-price ratio.

22. The year-end data for 1988 (table 3) show that the shares of fixed assets "used for industrial production" (OPF*/OF*) were 0.810 (state) and 0.842 (collective).

23. Simultaneity bias will result if positive productivity shocks lead to larger measures of average firm size, i.e., Cov(q,e) > 0. Note that this bias and the bias associated with measurement error should operate in opposite directions.

24. The data come from *China Urban Statistics, 1985* (London and Beijing: Longman Group and China Statistical Information & Consultancy Service Centre, 1985); and *Zhongguo chengshi tongji nianjian 1988* (China urban statistics yearbook, 1988) (Beijing: Zhongguo tongji xinxi cixun fuwu zhongxin and Zhongguo jianshe chubanshe, 1988).

25. The 1989 edition of the *China Urban Statistics Yearbook* omits the data on collective industry required to estimate a production function for that sector for 1988.

26. For a review of frontier production function techniques, see F. R. Forsund, C. A. K. Lovell, and P. Schmidt, "A Survey of Frontier Production Functions and Their Relationship to Efficiency Measurement," *Journal of Econometrics* 13 (1980): 101–15.

27. To be more specific, we (i) estimate the full "cleaned" sample and iterate, dropping out small numbers of observations at the extremities of the distribution of the residuals at each iteration, until two-thirds of the original observations have been dropped from the sample (62%–65% of those most off the production function and 2%–5% of those at the frontier); (ii) identify the range of within-period stability of α_k and α_m by adding in observations to make the sample more inclusive and by dropping observations to make the sample closer to a pure frontier function sample; and (iii) test the stability of the 1984 and 1987 quasi-frontier estimates within each of the two sectors. A more detailed description of this quasi-frontier estimation procedure appears in the annex.

28. The scale parameter σ is calculated as $1/(1 - \beta)$. The factor output elasticities (α_K, α_L, α_M) shown in eq. (1) and reported in table 6 are calculated by multiplying the parameter estimates for each of the factors in eq. (3) by σ.

29. Gary H. Jefferson and Gang Zou ("China: Sectoral Case Studies on Industrial Policy," Working Paper no. 8 [Structural Change Project of the World Bank, 1989]) discuss the concentration of losses within small state-owned iron and steel enterprises in Sichuan province.

30. In constructing table 7, we apply the 1984 values of α_k, α_l, α_m, and β for 1980 and 1984 and use the 1987 values for 1988.

31. The number of independent accounting units in 1980, 1984, and 1988 was 62,437, 63,295, and 72,494 in the state sector and 263,378, 321,039, and 343,866 in the collective sector (SOE data for 1980 and 1984 from *TJNJ 1981* [n. 1 above], p. 260, and *TJNJ 1985*, p. 376; other data provided by the SSB).

32. This theme is developed in Gary H. Jefferson, "A Framework for Analyzing the Convergence of Factor Returns: The Case of Chinese Industry," Working Paper no. 245 (Brandeis University, Department of Economics, Waltham, Mass., 1990).

33. To express real fixed assets in nominal terms, we multiply DNPF by DEFK, the deflator for fixed assets. The result is a measure of fixed assets that corresponds to GV, our measure of industrial output in terms of current prices.

34. See the annex for estimates of MRF, the major repair fund.

35. These results do not necessarily conflict with the common observation that Chinese enterprises appear to employ more resources than are required

to complete their present tasks. Our calculations measure marginal productivity by estimating the impact of marginal changes in resource endowment assuming that the intensity of utilization of cooperating factors remains unchanged.

36. Similar findings, based on two enterprise samples, are reported by Gary H. Jefferson and Wenyi Xu, "The Impact of Reform on Socialist Enterprises in Transition: Structure, Conduct, and Performance in Chinese Industry," *Journal of Comparative Economics* 15, no. 1 (1991): 45–64. Unlike the present study, however, their analysis evaluates the convergence of average rather than marginal revenue products.

37. These figures exclude retirements, which involved another 1.2% of the work force. See *Zhongguo laodong gongzi tongji nianjian 1989* (China labor and wage statistics yearbook, 1989) (Beijing: Laodong renshi chubanshe, 1989), pp. 203, 206.

38. Gross output value of collective industry (including village-level units) surpassed the gross value of agricultural output (both at current prices) by 12.3% (see *TJNJ 1989,* [n. 1 above], pp. 17, 263).

39. Chen et al., "Productivity Change in Chinese Industry" (n. 2 above), p. 585.

40. *Jiage lilun yu shijian* (Price theory and practice) 5 (1988): 57; Jefferson and Xu; Kyoichi Ishihara, "China's Multiple Price System," *JETRO China Newsletter,* no. 80 (1989), pp. 2–9.

41. *Shijie jingji daobao* (World economic herald) (November 14, 1988).

42. Gary H. Jefferson, "A Preliminary Investigation into Sources of Variation in Productivity Growth among China's Key Industrial Sectors," in *Adaptive Innovation in Asian Economies,* ed. M. Dutta (Greenwich, Conn.: JAI Press, in press).

43. Thomas G. Rawski, "How Fast Has Chinese Industry Grown?" Research Paper Series no. 7 (World Bank, Country Economics Department, Socialist Economies Reform Unit, Washington, D.C., 1991).

44. These data appear in *TJNJ 1989,* p. 508.