The Coast-Noncoast Income Gap, Productivity, and Regional Economic Policy in China

by Belton M. Fleisher and Jian Chen[1]
Department of Economics
The Ohio State University
Columbus, OH 43210
and
Department of Economics
Kenyon College, Gambier, OH 43022

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Abstract

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We postulate that inferior factor productivity in China's noncoastal provinces is a principal reason for their lower economic growth despite high investment rates relative to coastal provinces. Using the residual from a fixed-effect Solow growth model for the years 1978-93, we find that TFP is roughly twice as high in the coastal provinces. We estimate that one variable subject to direct policy control, investment in higher education, helps explain the productivity gap and exhibits a very high rate of return, greater in noncoastal provinces. We estimate that investment in infrastructure has a moderate rate of return that is higher in coastal provinces, although investment in infrastructure may be necessary to attract and retain university graduates in the interior.

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1 Introduction

This paper is an attempt to understand the persistent and widening income gap between coastal and interior China and to suggest appropriate policies to help the lagging interior provinces catch up to their more prosperous counterparts. China's extraordinary economic growth over the past 15 years has not been shared equally among its provinces and regions. (See, for example, Chen and Fleisher, 1996 and Yang and Wei, 1996.) In particular, rising per-capita income in 10 coastal provinces[1] has outstripped growth in the interior, so that between 1978 and 1993 the coast/noncoast ratio of mean GDP per capita grew from 2.53 to 2.82, or 11 percent. As figure 1 shows, the widening disparity between the coast and interior has been sufficient to swamp forces working toward provincial income equality within the coast and noncoastal regions. Although the all-province coefficient of variation of provincial per capita real GDP was greater in 1993 than at the beginning of the Communist era, since 1978 this inequality measure has declined within the favored coastal provinces and within the less-advantaged interior.

Aware of the political danger and perhaps also sensitive to the inequity of favoring coastal development, the central government has taken steps to promote the growth of enterprises in the interior, focusing particular attention on steps to encourage investment in rural enterprises. (Yang and Wei, 1996) Evidently this strategy has yet to produce the desired results. One problem with relying on an accelerated rate of investment in the interior is that its success depends on productivity in the interior being not significantly inferior to productivity in the coastal provinces. Unfortunately there is evidence to the contrary. Chen and Fleisher (1996) show that the growing coast-noncoast income differential is not attributable solely to greater domestic investment or even to greater foreign direct investment flowing

[1] We include Beijing and exclude Guangxi and Hainan because of inadequate data for this study.

into the coastal provinces. Actually, the share of investment in provincial GDP is greater in the interior than in the coastal provinces, although foreign direct investment is clearly greater on the coast. It seems clear that the coast-noncoast gap reflects forces not yet identified.

We hypothesize that a major cause of the persistent and widening income gap between the coast and interior is lower factor productivity in the noncoastal provinces. We approach the problem as one of differences in total factor productivity (TFP) levels and rates of TFP growth. Our aim in this paper is to test the hypotheses of differential TFP and TFP growth, to identify factors contributing to the productivity gap, and to derive implications for policies that may help the interior provinces approach parity with their coastal counterparts.[2]

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[2]Kam-tim Lau and Josef Brada (1990) and Yanrui Wu (1995) report deterministic and stochastic frontier production-function estimates, respectively, for China which identify the contributions of technology and technical efficiency to total factor productivity (and its growth). Lau and Brada point out that knowing the contribution of each component to TFP growth is important in forecasting how long current growth trends will continue, because the contribution of increased technical efficiency to TFP growth is constrained by the degree to which current production lies inside the production-possibilities frontier. Lau and Brada find substantial improvement in technical efficiency between 1978 and 1985 (the last year of their data) for the output of independent accounting units in state-owned enterprises. In contrast, Wu finds little contribution of increased technical efficiency to TFP growth over the period 1985-1991 using production data for all sectors. We have chosen not to use a frontier estimation approach for two reasons: (1) The first reason is that the accuracy of allocating the "residual" of the production relationship between technical efficiency and technological progress depends critically on the accuracy with which inputs have been measured. Lau and Brada used capital-stock data that were corrected for investments in "non-productive" capital and for changes in the cost of capital. Wu, however, because his study focused on all sectors, was unable to correct his measures of capital for the first source of inaccuracy. (We make an indirect attempt to do so in "explaining" TFP across provinces.) (2) The second reason for not attempting to identify separately the technical efficiency component of TFP is, in a sense, philosophical, and rests on the belief that there is an inherent arbitrariness in distinguishing between the level of technology and the level of technical efficiency.

In our view, there are three causes for any given enterprise not to produce on the production frontier defined by the world's "best available" technology, which is generally available to all firms and which grows at an exogenously determined rate: (i) absence of physical capital in which the technology is embodied; (ii) lack of human capital, or knowledge of the best available technology; and (iii) adverse incentives due to market institutions, government controls, etc. Economic reforms since 1979 are designed to take care of item (iii) and are evidently reflected in the increased efficiency identified by Lau and Brada in the early years of the reform era. If TFP is below its maximum due cause (i) or (ii) is this necessarily "inefficient?" The answer depends in part on one's view of capital markets, available resources, capital constraints, and so on. The current study includes factors (i) and (ii) as possible explanations of provincial differences in TFP. The

The rest or the paper proceeds as follows. In section 2 we outline the basic theoretical and econometric procedure for identifying TFP and TFP growth across provinces. In section 3 we report our econometric results and attempt to identify variables responsible for differences in provincial TFP and TFP growth. The last section summarizes our results and draws policy implications.

2 MODELING TFP AND TFP GROWTH

We assume a Cobb-Douglas production function with neutral technology,[3]

$$Y_{i,t} = A_{i,t} K_{i,t}^{\alpha} L_{i,t}^{1-\alpha} e^{\epsilon_{i,t}} \tag{1}$$

where i and t index the provinces and time, respectively. In the spirit of what is now graduate-textbook economic growth modeling, we specify $A_{i,t} = A_{i,0} e^{g_i t}$ as the systematic component of TFP at time t, which includes all factors contributing to output other than labor L and physical capital K at time t; g_i as the rate of technological change, and $\epsilon_{i,t}$ as an error term with the usual properties, which may also be viewed as random productivity shocks.

The labor force evolves as $L_{i,0} = e^{n_i t}$, where n_i is the rate of labor-force growth. Output per worker, a close correlate of income per capita, is $y_{i,t} = A_{i,t} k_{i,t}^{1-\alpha}$ where $y \equiv Y/L$ and $k \equiv K/L$. Obviously, policies designed to raise per-capita output and income by stimulating investment in new capital will be less effective in precisely those provinces they are designed to help insofar as low TFP rather than a low ratio of capital to labor is the main cause of low income.

Our approach to deriving estimates of and explaining TFP consists of two stages. In the first stage, we use a Solow growth model based on equation

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main focus of this paper is on policy variables that may be manipulated to alter the coast-noncoast income and productivity gap. To the extent we can identify and quantify such variables and their likely impact on TFP, whether they are considered technology enhancing or efficiency enhancing seems to us to be a moot point.

[3] G. S. Maddala (1979) points out that ". . . within the class of functions . . .Cobb-Douglas, generalized Leontief, homogeneous translog, and homogeneous quadratic, differences in the functional form produce negligible differences in measures of multi-factor productivity." Guang H. Wan (1995), however argues that alternative specifications (e.g., neutral, labor-augmenting) can influence estimates of the degree of technical change. We assume in this paper that whatever errors may be introduced by our assumption of neutral technical change apply equally across all provinces, so that our interprovincial comparisons are unaffected.

(1). Taking logs and imposing the condition that aggregate saving S equals aggregate investment $\dot{K}$, in the steady state, we can derive

$$\ln y_{i,t} = \frac{1}{1-\alpha}(\ln A_{i,0} + g_i t) + \frac{\alpha}{1-\alpha}\ln s_{i,t-1} - \frac{\alpha}{1-\alpha}\ln n_{i,t} + w_{i,t}, \quad (2)$$

where the variable s represents the share of investment (net of depreciation) in income (lagged one period to allow for new capital to come "on line").

We want to apply this version of the Solow growth model to annual, panel data, and it is implausible to assume that the provincial economies attain their steady states each year. A more realistic alternative is to assume that convergence to the steady state occurs at the rate λ $(0 < \lambda < 1)$ such that

$$\begin{aligned} \ln y_{i,t} - \ln y_{i,t-1} \quad = \quad & (1 - e^{-\lambda t})\left[\frac{1}{1-\alpha}(\ln A_{i,0} + g_i t) + \frac{\alpha}{1-\alpha}\ln s_{i,t-1}\right. \\ & \left. - \frac{\alpha}{1-\alpha}\ln n_{i,t}\right] - (1 - e^{-\lambda t})\ln y_{i,t-1} + u_{i,t}. \quad (3) \end{aligned}$$

Equation (3) provides for direct estimates of provincial TFP ($A_{i,t}$), which as specified above consists of a systematic component, $A_{i,0}e^{g_i t}$, and random shocks, u_t. There are two advantages to using this growth-model formulation as a basis for deriving our TFP estimates. (1) We estimate all production-function parameters directly and simultaneously. That is, we don't have to rely on an indirect procedure such as applying "factor share" estimates to factor-input levels or growth to obtain estimates of TFP and TFP growth. Such an indirect procedure, although time-honored in the general growth literature and some studies of the Chinese economy[4] is particularly untrustworthy in a transitional economy, such as China's, in which observed pecuniary factor returns cannot be assumed to equal factor marginal products. (See, for example, Chen, *et al.*, 1988; Fleisher, Dong, and Liu, 1996.) (2) An additional advantage of this framework is that only data on annual investment are required, rather than data on the capital stock.[5]

2.1 Explaining Technological Change

In the second stage of our approach to identifying the determinants of TFP, we make the standard growth accounting assumption that the error term

[4]See, e.g., Wolff (1991) and a list of selected works on productivity change in the Chinese economy in Wan (1995).

[5]Discussion of difficulties in using capital stock data in China to estimate aggregate production functions can be found in Chen, *et al.* (1988) and Chow (1984), especially pp. 202-205.

in the above equations, $u_{i,t}$, represents provincial productivity shocks, and we define TFP in year t as $\tau_{i,t} = A_{i,0} + g_i t + u_{i,t}$. We then specify the following panel and cross-section regression equations, respectively, to explain provincial TFP differentials.

$$\begin{aligned} \ln \tau_{i,t} &= \alpha_0 x_0 + \sum_{m=1}^{5} \alpha_m x_{m,i,t-1} + \\ &\quad + \alpha_6 C + \alpha_7 t + \alpha_8 Ct + \alpha_9 \ln \tau_{i,t-1} + v_{i,t}, \end{aligned} \tag{4}$$

where the right-hand variables and hypothesized qualitative relationship with TFP are
x_0 = constant term;
x_1 = a measure of investment in housing (to correct for the inclusion of expenditure on new housing in total investment), < 0;
x_2 = a measure of the vintage of the physical capital stock, < 0;
x_3 = a measure of investment in human capital, > 0;
x_4 = a measure infrastructure (highways, railways, and waterways), > 0;
x_5 = foreign direct investment (FDI) as a share of total investment, > 0;
$C \equiv$ a dummy variable = 1 for coastal provinces;
t = the year of observation ($1978 = 1 \cdots 1992 = 15$); and
$v_{i,t} \equiv$ an *iid* error term.

Full definitions and sources of the variables are included in the Appendix.[6] We first estimate equation (4) with only the coastal dummy and trend variables included to obtain a basic estimate of the coast-noncoast differential in TFP and TFP growth. To the extent the remaining variables listed above correlate positively (negatively) with TFP and are present in greater (smaller) magnitude in the coastal provinces, the coefficient of the coastal dummy will diminish when the additional variables are included in the regression. As mentioned briefly in the preceding list of variable definitions, a variable representing housing investment (growth in floor space per person) is included, not because we believe housing contributes positively to TFP (although one could construct an argument that, at least at low levels, improved housing leads to healthier and more productive workers). Rather, it is included in the TFP regressions because we lack data on both capital stock and investment that are net of expenditure on housing construction

[6]Unfortunately, variables x_4 (infrastructure) and x_5 (FDI) are not available annually 1978-93. Therefore in our empirical work we have treated them as "environmental" variables, using a single value as applicable to all years in our sample. Details are contained in the notes to table 2.

and other forms of investment in "nonproductive" capital. Not only is available investment data gross of construction of housing by firms that provide housing for their employees, but the data also include housing investment undertaken by households and individuals. To the extent housing investment is overstated in equations (1)-(3), TFP is underestimated.[7] Therefore, the hypothesized sign of the regression coefficient for the housing variable is negative.[8]

The rationale for the role of vintage as contributing to TFP and TFP growth is neatly summarized by Wolff (1991). Although Wolff uses rate of change of the capital stock as a proxy for vintage, we have chosen to define variable x_2 as a weighted average of the age of existing capital, specifically, $V_t = \sum_{j=0}^{t} \left[\frac{I_{i,j}}{\sum_{j=0}^{t} I_{i,j}} (t-j) \right]$, where I_j is real accumulation of fixed assets.[9] Wolff identifies five "avenues" that have been suggested in the literature via which capital accumulation may be positively correlated with technological efficiency. (1) New technology is *embodied* only in new capital. Thus the rate of change of the capital stock (investment/capital stock) positively correlated with TFP. (2) Investment in new capital may be correlated with the adoption of improved management techniques. (3) When new capital stock is acquired management and workers require time to learn how to use it effectively. This *learning by doing* in the spirit of Arrow (1962) contributes to TFP growth. The implication would also seem to be that unless the

[7] Chen, *et al.*(1988) report estimates of production functions for state industry in which capital- stock data have been purged of housing and other "nonproductive" capital. Jefferson, Rawski, and Zheng (1992) use corrected data for state and collective industry. It would be ideal for us to use such net capital stock data for each province, but constructing such data is a task that is far beyond our current resources.

[8] In order to solve the problem that annual data for this variable are not available 1978-93 we use an instrument for housing in estimating equation (4). The instrument is obtained by regressing a measure of housing area (square meters) per capita on per-capita real income. The "predicted" level of per-capita housing is then used as the measure of variable x_1.

[9] Data for accumulation of fixed assets is available after 1952 for all provinces in our sample. We deflate using a price index obtained from series on construction in nominal prices and construction in fixed prices. Chen, *et al.* (June, 1988) assert that the data on construction in fixed prices are unreliable. However, our alternative is to use the provincial National Income deflator that can be obtained by comparing National Income and National Income at Fixed Prices. We chose to use the construction deflator on the assumption that using it would provide an index closer to that which is correct for accumulation than would using the alternative. We also used the same data to construct a variable$(\frac{\Delta K}{K})_{i,t} = \frac{I_{i,t}}{\sum_{j=0}^{t} I_{i,j}}$, which is conceptually similar to the variable used by Wolff. The empirical results are not very sensitive to which of these variables is used to estimate equation (4).

new capital embodies more advanced technology, the initial effect may be to lower TFP, followed by rising TFP as learning-by-doing occurs.[10] (4) In the fourth reason for correlation, causation is reversed. A high level of TFP raises the productivity and profitability of new investment, thus leading to a more rapid rate of capital accumulation. Finally, (5) macroeconomic effects via the impact of investment on aggregate demand may raise observed TFP. We find the embodiment hypothesis to be the particularly appealing. As far as higher TFP leading to higher rates of investment, our inclusion of additional variables hypothesized to contribute to TFP should control for this reverse causation, at least in part. Obviously, we cannot be sure that we can control completely for causation running from TFP to the pace of capital accumulation.

The contribution of human capital to production is by now part of the received knowledge. It would be appropriate to include investment in human capital parallel to physical-capital investment in equation (3). We do not do this, because data on the actual magnitude of human-capital investment are very difficult to construct. Doing so for China would be an extremely time- and resource-expensive project. (See Jorgenson and Fraumeni, 1992.)[11] We therefore have elected to estimate the impact of human capital as reflected in education in the second stage of our research.

The inclusion of infrastructure as measured by the aggregate length of water, paved highway, and trunk railway per square kilometer of area, hardly needs justification. It has been pointed out that investment in infrastructure may be dependent on the level of income and hence may be endogenous in an explanation of TFP. (See, for example, Fernald, 1996.) We have not attempted to correct for such possible endogeneity in estimating equation (4). Insofar as funding of major, inter-provincial, transportation routes is determined at the state level, it seems plausible that nationwide income rather than provincial income is the determining resource constraint. However, to the extent the allocation of funds for infrastructure investment is influenced by redistributional goals, a negative feedback from provincial productivity levels to infrastructure investment may occur.

We include foreign direct investment (FDI), hypothesizing that, originating in firms in major industrialized nations and often supplied by overseas Chinese in Hong Kong, Taiwan, and southeast Asia, it embodies the latest in production and management technology and is a source of technology

[10] Alwyn Young (1992) emphasizes the negative aspect of learning by doing on TFP growth in a comparison of Singapore and Hong Kong.)

[11] Despite lack of data on human-capital investment as such, Mankiw, Romer, and Weil (1992) do include a proxy in their well-known study.

transfer to the provinces that receive it, over and above the embodiment of new technology in new capital, in general.[12]

We follow Wolff (1991) in including lagged TFP, τ_{t-1}, in equation (4). Wolff emphasizes three factors that are hypothesized in the growth literature to lead to convergence of labor productivity across countries and regions: (i) convergence in capital:labor ratios, which is captured by equation (3); (ii) the embodiment effect, captured by the inclusion of variable x_2; and (iii) the "catch-up" hypothesis, which is based on the disembodied diffusion of technology from advanced to more backward regions. If disembodied technology transfer is a significant factor explaining provincial TFP growth, then we expect $0 < \alpha_9 < 1$.

3 ECONOMETRIC RESULTS

The estimate of equation (3) is shown in table 1.[13] The coefficient of lagged per-capita GDP indicates a very rapid rate of convergence (about 75% per year), but it must be emphasized that this is a strongly conditional convergence to very different levels of per-capita income, as indicated by the estimated values of A_0. Based on the estimated coefficient of $ln(I/Y)$, the implied elasticity of capital is approximately 0.2, implying a labor elasticity of approximately 0.8. This is at the low end of estimates of the elasticity of production with respect to physical capital reported in the literature. (See, for example, Chen and Fleisher, 1996, Chow, 1994, and Chen, *et al.*, 1988.) The regression coefficients of greatest importance for the research reported here are those of the 25 provincial dummy variables and their interaction with trend. These are the estimates of $A_{i,0}$ (in 1978 prices) and g_i for each province reported in the lower portion of table 2. All these coefficients are highly significant, ranging from 6- to 13 times their standard errors, and to save space we repress reporting the standard errors or t-statistics. The estimates of $A_{i,0}$ vary greatly, from a low of 100 1978 *yuan* for Guizhou to a high of 998 1978 *yuan* for Shanghai. The TFP growth estimates exhibit a

[12] See Shang- Jin Wei (1993) for a similar view.

[13] The empirical formulation of equation (3) uses the arithmetic form, rather than the log of the employment-change variable, n, because annual employment growth in some provinces is occasionally negative. Because of this difficulty, it is impossible to impose the constraint on the estimated factor elasticities implied by the constant-returns-to-scale assumption implicit in equations (1)-(3).

Table 1: Estimates of TFP and TFP Growth [a]

Dependent variable log difference real GDP per capita (1978-98)		
Independent Variable/Province	Regression Coefficients (absolute t-statistics)[b]	
$ln(I/Y)$	0.11 (7.39)	
Employment growth rate[c]	-0.27 (1.98)	
lny_{t-1}	-0.53 (12.4)	
	TFP ($A_{i,0}$)	TFP Growth (g_i)
Beijing (C)[d]	518	.050
Tianjin (C)	502	.039
Hebei (C)	165	.067
Shanxi	182	.050
Innner Mongolia	144	.051
Heilongjiang	282	.034
Shanghai (C)	998	.039
Jiangsu (C)	233	.070
Zhejiang (C)	185	.086
Anhui	165	.067
Fujian (C)	142	.079
Jiangxi	137	.066
Shandong (C)	160	.076
Henan	131	.068
Hubei	179	.064
Hunan	153	.055
Guangdong (C)	173	.095
Sichuan	137	.064
Guizhou	100	.064
Yunnan	107	.073
Shaanxi	144	.060
Gansu	153	.064
Ningxia	153	.061
Xinjiang	148	.072
Mean of Coastal Provinces	340	.065
Mean of Noncoastal Provinces	154	.062

[a]Jilin,Guangxi, Hainan, Qinghai, and Tibet are excluded because of insufficient data.

[b]The TFP and TFP Growth coefficients are all highly significant; therefore, to conserve space, we do not show standard errors or t-statistics.

[c]Log of employment change cannot be used because some year-to-year changes are negative.

[d]The letter C indicates a "coastal" province.

much smaller range of variation, from a low of 3.4% per year (Heilongjiang) to a high of 9.5% (Guandong). The mean rate of TFP growth across the 25 provinces represented in table 2 is 6.3%, and suggests that productivity growth contributed a substantial share–about 80%– to the average provincial growth rate of per- capita GDP of 7.8%. This contribution to overall growth can be compared with Young's (1992) estimate of a 56% contribution of TFP growth to the increase in output per worker in Hong Kong between 1971 and 1990 and Wolff's (1991) estimates of a 52-66% contribution for the G-7 countries between 1950 and 1979.[14] An indication of a TFP catch-up process at work is the negative correlation between TFP levels and annual growth rates of -0.59, which can be visualized in figure 2. Even without the extreme observation of Shanghai, a negative correlation between TFP and TFP growth (-0.57) is apparent.

Our estimates of the determinants of TFP and TFP growth is contained in table 2. In the empirical application of equation (4), we have used both the level and first difference of TFP (ΔTFP) as the dependent variable. In the TFP regression, we first include only the coastal dummy, a trend and trend x coastal interaction term. (The trend and trend x dummy are excluded from the ΔTFP regression.) In these regressions, we see that the coastal TFP in the coastal provinces is on average 85% $(100(e^{.62}-1))$ higher than in the interior but that the average growth rate of coastal TFP is not significantly different than in the noncoastal provinces. We obtain a similar result in the first-difference form of the regression, that there is very little evidence of more rapid TFP growth in the coastal provinces when other factors determining TFP are not held constant. When the additional explanatory variables are added to the TFP equation, the adjusted R^2 increases from 0.56 to 0.98, and the constant term and coastal dummy variable fall significantly both in magnitude and in statistical significance. The additional variables appear to account for virtually all of the coast/noncoast productivity gap. The t-statistic of the interaction between the coastal dummy and trend rises from 0.3 to 1.3, but the regression coefficient is unaffected, indicating the possibility of a small net TFP growth advantage for the coastal

[14] Our estimates of TFP growth are higher than obtained in other studies of China cited throughout this paper. We have no definitive explanation of this discrepancy. However, we conjecture that a plausible explanation may lie in the inclusion of lagged per-capita GDP in equation (3). Our specification is correct if we are not willing to assume that provincial GDP levels are typically observed in their steady state. Another possible explanation is the relatively large weight estimated for the elasticity of labor in equation (3). As long as any upward bias in our estimates applies in equal proportion to both coastal and noncoastal provinces, then our analysis of the causes of the coast-noncoast income gap will be largely unaffected.

Table 2: Determinants of TFP

	Dependent variables			
Independent Variables[a]	$ln\,\tau_i$		$ln\,\tau_i - ln\,\tau_{t-1}$	
Constant	5.07 (94.55)	0.70 (4.10)	0.062 (11.42)	0.60 (4.55)
Coastal Dummy	0.62 (7.48)	0.010 (1.0)	0.011 (1.27)	0.025 (2.00)
Trend	0.061 (9.75)	0.003 (1.56)		
Coastal Dummy x Trend	0.003 (0.32)	0.003 (1.10)		
$ln\,\text{Vintage}_{t-1}$		0.004 (0.12)		-0.20 (0.65)
$ln\,\text{Housing}_{t-1}$		-0.30 (0.48)		-1.99 (5.60)
$ln\,(\text{University Grads/Pop})_{t-1}$		0.017 (1.40)		0.22 (1.58)
Trans. Route Length/Sq. Km.		0.058 (1.40)		0.22 (1.58)
FDI/I		0.155 (0.64)		0.42 (1.83)
$ln\,\tau_{t-1}$		0.91 (52.3)		-0.057 (4.36)
Adj. R^2	0.56	0.98	-0.016	0.14

[a]For full variable definitions, see Appendix. In the ΔTFP formulation, *ln* Housing is used in difference form. *Ln* Vintage and *ln* (University Grads/Pop) are not differenced. Transportation is expressed as 1/8 the 1994-1986 difference, and FDI/I is the sum of FDI 1984-93 divided by mean accumulation (I), as in the level equation.

provinces. The investment and housing variables are statistically indistinguishable from zero. The regression coefficients of the variables representing human capital, transportation infrastructure, and foreign direct investment are of the predicted sign and all have moderately high t-statistics (1.4-2.6). The regression coefficient of lagged TFP is highly significant and implies that disembodied technology transfer causes TFP to grow (*cet. par.*) at a rate of approximately 0.9% per year less per 1% increase in TFP across provinces.

When the additional explanatory variables are included in the ΔTFP regression, the estimated net coastal advantage in TFP growth increases, as indicated by increase in the coefficient of the coastal dummy from 0.010 to

0.025 and an increase in its t-statistic from 1.0 to 2.0. In other words, the estimated TFP growth advantage of the coastal provinces is more than doubled when the additional variables are included in the regression. Evidently, some of the additional explanatory variables positively (negatively) correlated with TFP growth are less (more) prevalent in the coastal provinces. Lagged TFP remains highly significant, although it is somewhat smaller than 1 minus the coefficient of lagged TFP in the TFP regression, as would be expected if the right-hand variables in the TFP and ΔTFP regressions were identical. The coefficient of capital vintage is of the hypothesized sign and has a somewhat higher t-statistic, but is still insignificant by any conventional standard. In other words, there is little evidence that technical progress is embodied in new capital as such in the Chinese case. The housing variable has a much larger coefficient (in absolute value) and a much higher t- statistic. This is consistent with its serving the purpose of correcting for inclusion of nonproductive items in total investment. One possible explanation of the increase in significance is that there is more collinearity in the TFP equation between lagged TFP and the housing variable than in the ΔTFP equation, where they are expressed in difference form.

The coefficient of the natural log of the human-capital variable, university graduates/population is significant and almost the same magnitude in both the level and change-formulations of the TFP regression. The range of this variable is quite large, ranging from a low of 0.0006% of the population to a high of 0.35%. The estimated regression coefficient implies that for a typical province, a doubling of the ratio of the annual flow of university graduates:population would lead to 1.7% increase in the level of TFP and and a similar increase in the annual rate of TFP growth (about a 25% proportionate increase in the rate of TFP growth for a typical province).

The regression coefficient of the infrastructure variable retains approximately the same level of statistical significance in both the level and change regressions. Again, the range of variation among the provinces is immense, from 0.017 km of transportation routes:1 square km. of provincial area to over 1 km:1 square km. The estimated coefficient implies that adding 0.1 km./square km. to the transportation routes of a typical province would increase TFP by 0.6% and the rate of TFP growth by about 0.3% per year.

Cumulative FDI as a proportion of mean annual investment ranges from a low of 0.1% to a high of 10.1% across the twenty-five provinces in our sample, with a provincial mean of 1.7%. The estimated regression coefficient in the level regression is statistically insignificant, but taken at face value implies that increasing the FDI:I ratio for a province at the bottom of the distribution to the sample mean would raise TFP by 0.24%. The estimated impact on TFP growth is marginally significant and implies that raising the FDI:I ratio from the bottom of the distribution to the sample mean would increase TFP growth by about 0.7 percentage point per year. Although FDI cannot be easily construed as a policy variable within the direct control of the central or provincial governments, its influence on TFP and TFP growth through embodiment of new technologies and managerial skills is conceivably quite important. To the extent that improvement of other factors influencing TFP (e.g. education and infrastructure) attract additional FDI, there may be a multiplier effect on the payoff to these activities.

4 EVALUATION AND POLICY IMPLICATIONS

We have estimated that two variables subject to direct policy control of both the central and provincial governments have a positive impact on TFP and TFP growth. One of these variables, investment in human capital is quite significant statistically, and its magnitude is rather large. The other variable, investment in transportation infrastructure, is not quite as significant in the regressions, but our point estimate of its potential impact on the profitability of new investment is also substantial.

To put these relationships into perspective, we first consider the impact of education. A useful way to frame the net social pecuniary return to additional higher education is to use a standard human-capital formulation in which the flow return of increasing the number of university graduates per year by the proportion $\Delta E/E_j$ in province j is (assuming no depreciation and infinite lifetimes) $\alpha_3 \frac{\Delta E}{E_j} Y_j$ where α_3 is the estimated elasticity of TFP with respect to university graduates, E_j is the annual number of college graduates in province j, and Y_j is a measure of aggregate provincial output, e.g. GDP. The one-year cost of such an investment would be $\frac{\Delta E}{E_j} E_j(\beta \frac{Y_j}{N_j} + D)$ where we assume a Cobb-Douglas production function, β is the elasticity of output with respect to labor, N_j is a measure of the labor force in province j, and D is the direct cost in terms of physical capital, instructional staff, support staff, etc. of one year of university education for one person. The expression $\beta \frac{Y_j}{N_j}$ is the indirect cost, or foregone output for one typical individual (assume a high-school graduate) who leaves the labor force for one year to attend college. By setting the return and cost expressions equal to each other, and if we assume that the direct cost of one year of college is equal to the foregone-production cost[15] we can solve for the implicit rate of

[15]This is only a simplification. The nature of the solution is basically unaffected by this

return to higher education, ρ, obtaining

$$\frac{\alpha_3}{2\beta \frac{E_j}{N_j}} + 1 = (1+\rho_j)^4. \tag{5}$$

Equation (5) illustrates that the payoff to investment in human capital is greater, the greater the elasticity of TFP with respect to adding new university graduates and the smaller is the elasticity of production with respect to labor and the ratio of the current flow of new college graduates relative to the labor force.

To obtain a feel for the numerical magnitudes involved, we apply the human-capital framework to the cases of Beijing and Sichuan, China's most populous province. In 1986, for example, Sichuan had nearly the same number of new college graduates as Beijing (approximately 25,000 versus 27,000, respectively), but about 10 times the population (100,000,000 versus 10,000,000). The ratio of graduates/population in Sichuan is about equal to the national provincial average, which is only one-tenth the ratio in those provinces with the greatest number of university students relative to population, such as Beijing, Shanghai, and Tianjin. We use 0.017 from table 2 as our estimate of α_3, and to adjust for the ratio of the population that is employed (approximately 50% in 1986), we set $\beta = 1$. We thus calculate $\left[1 + \frac{0.017}{.00050}\right]^{1/4} = 2.44$ for Sichuan and $\left[1 + \frac{0.017}{.0054}\right]^{1/4} = 1.42$ for Beijing. That is, we arrive at an estimate of an annual rate of return to investment in higher education in Sichuan province of about 144%, while for Beijing it is about 42%.

Obviously, the distribution of college graduates among the provinces is highly skewed. Thus doubling the university graduates:population ratio for an average province, which our estimate of α_3 implies would raise provincial GDP by 1.7%, would still leave a large gap in comparison with provinces at the high end of the distribution. While our estimate of the rate of return to higher education is quite high when compared to estimates based on earnings data for many other economies, both advanced and emerging (e.g. George Psacharapoulos, 1992), extraordinarily high returns to university education have also been estimated using micro production data for the Chinese paper industry. (See Fleisher, Dong, and Liu, 1996.) The estimated rate of return to investment in human capital in China also appears to be quite high in comparison to the return to investment in physical capital. For example, Chow (1994, p. 207) estimates the marginal product of physical capital

assumption.

Table 3: Estimated Rates of Return

Province	University Education	Infrastructure
Beijing (C)	0.42	0.82
Tianjin (C)	0.66	1.62
Hebei (C)	1.43	0.32
Shanxi	1.21	0.28
Innner Mongolia	1.27	0.14
Liaoning (C)	1.01	0.44
Heilongjiang	1.11	0.26
Shanghai (C)	0.52	2.88
Jiangsu (C)	1.12	0.54
Zhejiang (C)	1.29	0.38
Anhui	1.41	0.36
Fujian (C)	1.26	0.16
Jiangxi	1.28	0.18
Shandong(C)Henan	1.50	0.40
Hubei	1.06	0.32
Hunan	1.35	0.20
Guangdong (C)	1.36	0.26
Sichuan	1.44	0.22
Guizhou	1.60	0.14
Yunnan	1.59	0.11
Shaanxi	1.97	0.22
Gansu	1.08	0.16
Ningxia	1.21	0.14
Xinjiang	1.24	0.16
Mean of Coastal Provinces	1.04	0.78
Mean of Noncoastal Provinces	1.29	0.22

to be about 0.16 *yuan* per *yuan* of physical capital, which is equivalent to the rate of return if we ignore depreciation. Bearing in mind that we have omitted consideration of any multiplier effects operating through increased profitability of investment attracting more domestic and foreign investment, leading to a higher capital/labor ratio and higher ratio of foreign investment in total capital formation, the return to providing additional human capital, and its potential effect on the coast/noncoast income gap seems large, indeed.

The second policy variable subject to direct control by both the central and provincial governments is investment in infrastructure, which is represented in this study by the length of highway, railway, and water transportation routes per square kilometer of area. We can calculate the rate of return to investment in infrastructure in a manner similar to that used to calculate the return to investing in higher education. A measure of the flow return to increasing transportation-route infrastructure by a proportion $\frac{\Delta K}{K_j}$ (where K represents transportation routes in kilometers per square kilometer of provincial area) is $\alpha_4 \overline{K} \frac{\Delta K}{K_j} Y_j$. $\overline{K}$ is the provincial mean and $\alpha_4 \overline{K}$ is the estimated elasticity (at mean K) of TFP with respect to K. The commensurate cost of investing in infrastructure is $\frac{\Delta K}{K_j} K_j k_j^2 C$ where k_j^2 is the area of province j and C is the per-unit (kilometer) cost of infrastructure construction. The rate of return to infrastructure investment is then ρ in the following equation.

$$\frac{\alpha_4 \overline{K} Y_j}{K_j k_j^2 C} = \rho_j \tag{6}$$

Equation (6) illustrates that the payoff to investment in infrastructure is greater, the greater is the elasticity of TFP with respect to adding additional infrastructure, and the greater is provincial GDP relative to the product of the existing quantity of transportation routes/provincial area, provincial surface area, and to the unit construction cost of transportation routes. This estimated impact is approximately four times greater in the ΔTFP regression and slightly more significant statistically. If we assume that the ΔTFP estimate is less likely to be biased by omitted variables than the regression in which the level of TFP is the dependent variable and the level of infrastructure the right- hand variable, then the large coefficient is more likely to be correct.[16] We therefore have calculated rates of return based on the estimated regression coefficient from the ΔTFP regression.[17]

Our estimates of the rate of return to investment in human capital and

[16] In calculating the value of ρ_j for infrastructure, we interpret both coefficients as estimates of the effect of an additional unit of infrastructure on the level of TFP, because the Δ TFP regression includes as a right-hand variable an approximation of the first-difference of infrastructure.

We do not deal with the distinction between the TFP and ΔTFP regression coefficients of the education variable for two reasons. (1) Available data do not permit us to use annual data on the stock of university graduates in the TFP regression. (2) If there is a significant effect of human capital on TFP growth as well as on the level of TFP, then there is a commensurate effect on the opportunity cost of investment in human capital (depending upon what assumptions one cares to make about productivity growth in the education industry), which would offset growth in returns.

[17] When the change in the natural logarithm of the infrastructure variable is used in the ΔTFP regression, the estimated (constant) elasticity of TFP with respect to infrastructure is very close to the elasticity at the provincial means calculated on the basis of the regression coefficient reported in table 2.

infrastructure are shown in table 3. The contrast is striking in two respects. (1) Rates of return for investment in human capital far exceed those for investment in infrastructure on average and in almost all provinces, Beijing, Tianjin, and Shanghai being the exceptions. (2) Rates of return to infrastructure investment tend to be lower on average in the interior than in coastal provinces, whereas investment in human capital yields a return half again as high in the noncoastal as in the coastal provinces. One problem with our estimates of the rate of return for infrastructure investment reported in table 3 is that they are based on a common cost across all provinces. There are very limited data on provincial-specific construction costs for transportation routes. Using 1988 data[18] we derive widely different estimates of costs per kilometer across the provinces, with the mean for the coastal provinces being 1.4 times the all-province mean and that for the noncoastal provinces being 0.78 times the provincial mean. Dividing the mean rates of return in table 3 by these ratios implies a mean rate of return to infrastructure investment for the coastal provinces of 0.55 and for the noncoastal provinces 0.28, which does not reverse the conclusion that the rate of return to infrastructure investment appears to be considerably higher in the coastal provinces than in the interior and is uniformly lower than the return to investment in human capital.[19]

4.1 Policy Recommendations

In the introduction to this paper we noted that the central government has attempted to redress the coast-noncoast income gap in China by, among other means, fostering increased investment in the interior. One purpose of this study has been to provide some explanation of why, despite a higher rate of investment relative to GDP, the interior provinces have not grown more rapidly than their coastal counterparts in recent years. We suggested that one reason is the productivity of investment in the interior is not as high as in the coastal region. Our estimates of provincial TFP suggest that this explanation may have merit. Assuming the Cobb- Douglas production function of equation (1), the marginal product of capital in province j is $\alpha A_j (\frac{L_j}{K_j})^{1-\alpha}$. Presumably the policy of fostering higher investment rates in the interior is based on the superficially plausible assumption that the noncoastal provinces' higher labor:capital ratios are sufficient for a higher

[18]Statistical Yearbook of China 1987 and 1988.

[19]When province-specific correction factors are applied, the rate of return to infrastructure investment in Shanghai falls considerably below the rate of return to investment in human capital, and that in Tianjin becomes about equal to that on human capital.

marginal product of capital.[20] However, this assumption is falsified to the extent lower TFP offsets the interior's labor:capital advantage. We calculate the noncoast:coast ratio of marginal product of capital as approximately two-thirds.[21] implying that the marginal product of capital in the interior is only about 2/3 that in the coastal provinces.

The policy implications, we think, are quite clear. Efforts to reduce coast-noncoast income inequality that focus solely on encouraging traditional investment are bound to frustrated by low returns obtained unless they are supplemented with policies designed to increase TFP, and through it the productivity of new capital. Our results strongly suggest a massive increase in the stock of human capital–particularly college-trained managers and technical personnel–who are employed in the interior. An important component of such policies would doubtless include increasing the number of university students in the interior provinces. However, such efforts will fail unless new graduates are induced to remain in the interior and not migrate to jobs on the coast. Our estimates imply an extraordinary rate of return to investment in human capital in even the most favored provinces, much higher, on the face of it, than the return to investment in infrastructure. However, when we consider what policies might effectively induce new graduates to remain in the interior and also possibly encourage relocation from the coast, infrastructure not only in the form of transportation routes, but also in the public amenities that contribute to comfortable living, may well have a much higher rate of return than indicated by simple inference from estimated production-function parameters.

[20] The mean labor:capital ratio measured as indicated in the text in the noncoastal provinces is 1.31 times that in the coastal provinces.

[21] That is, $\frac{\frac{1}{10}\sum_{j=1}^{10} A_j^c \left(\frac{L_j}{K_j}\right)^{1-\alpha}}{\frac{1}{15}\sum_{j=11}^{25} A_j^{nc} \left(\frac{L_j}{K_j}\right)^{1-\alpha}} = 1.46$, based on our estimate of α from the equation (3) regression and estimates of TFP in 1992.

As mentioned earlier, we do not have capital stock data at the provincial level. However, we can approximate the relative capital-stock ratios across provinces with the data on cumulative real fixed investment from which we derived the index of capital-stock vintage used to estimate equation (4). (See appendix table A3.) With these data and our estimates of TFP reported in table 3, we can derive our calculation.

Our estimate of the coast:noncoast ratio of the marginal product of capital may be conservative, being based on a value of α that is higher than estimated in a number of other studies, as mentioned above. For example, for $\alpha = 0.6$, a not unreasonable value, the coast:noncoast ratio of marginal product of capital is 1.58, assuming the same coast:noncoast TFP ratio.

5 References

References

[1] Arrow, Kenneth, "The Economic Implications of Learning by Doing," *Rev. Econ. Stud.* 29: 155-73 June, 1962.

[2] Andrews, D. W. K., "Heteroskedasticity and Autocorrelation Consistent Covariance Matrix Estimation," *Econometrica* 59,3:817-858, May, 1991.

[3] Barro, R. J., "Economic Growth in a Cross-Section of Countries," *Q. J. Econ.* 106,2:407- 443, May, 1992.

[4] Barro, R. J., and Sala-i-Martin, X., "Convergence across States and Regions," *Brookings Papers Econ. Activity* no. 1, 107-182, 1991.

[5] Barro, R. J., and Sala-i-Martin, X., "Convergence," *J. Polit. Econ.* 100, 2:223-251, April, 1992.

[6] Box, G. and D. Pierce, "Distribution of Residual Autocorrelation in Autoregressive Moving Average Time Series Models," *Journal of the American Statistical Association* 65, 332: 1509-1526, 1970.

[7] Brauchli, Marcus W., "River of Dreams," *Wall Street Journal Midwest Edition* LXXII, 42:1, December 13, 1995.

[8] Chen, Kuan, 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* 114:243-266 June, 1988

[9] Chen, Kuan, Wang, Hongchang, Zhen, Yuxin, Jefferson, Garry, and Rawski, Thomas, "Productivity Change in Chinese Industry," *J. Comp. Econom.* 12, 4:570-91, 1988.

[10] Chow, Gregory C., *Understanding the Chinese Economy.* Singapore: World Scientific Publishing Co., 1994.

[11] Cochrane, John, "A Critique of the Application of Unit Roots Tests," University of Chicago (unpublished), 1987.

[12] Dickey, D. A. and W. A. Fuller, 1981 "Likelihood Ratio Statistics for Autoregressive Time Series With a Unit Root," *Econometrica* 49, 4:1057-72, June, 1981.

[13] Engle, R. F.., "Autoregressive Conditional Heteroskedasticity with Estimates of the Variance of United Kingdom Inflation," *Econometrica* 50:987-1007, 1982.

[14] Fernald, John, "How Productive is Infrastructure? Distinguishing Reality and Illusion with a Panel of U.S. Industries," working paper, (April, 1996). (Available from the author at Board of Governors, Federal Reserve System)

[15] Fleisher, Belton M., Keyong Dong, and Yunhua Liu, "Education, Enterprise Organization, and Productivity in the Chinese Paper Industry," *Econ. Dev. Cult. Change* 44, 3:571-587 (April, 1996).

[16] Fuller, W. A., *Introduction to Statistical Time Series*, New York: Wiley, 1976.

[17] Griffin, Keith and Renwei Zhao. Ed., *The Distribution of Income in China*. London: The Macmillan Press, Ltd., 1993.

[18] Hsueh, T., et. al., *China's Provincial Statistics 1949-1989.* Boulder,

[19] Jefferson, Gary H., Thomas G. Rawski, and Yuxin Zheng, "Growth, Efficiency, and Convergence in China's State and Collective Industry," *J. Comp. Econom.* 42,2:239-266 (Jan., 1992) CO.: Westview Press, 1993

[20] Jorgenson, Dale W. and Barbara M. Fraumeni, "Investment in Education and U.S. Economic Growth," *Scand. J. of Econ* 94, 0:S51-70 1992

[21] Lau, Kam-tim and Josef C. Brada, "Technological Progress and Technical Efficiency in Chinese Industrial Growth: A Frontier Production Function Approach," *China Econ. Rev.*1,2:113-24 (1990)

[22] Maddala, G.S. "A Note on the Form of the Production Functon and Productivity," in Measurement and Interpretation of Productivity:309-217. National Research Council, National Academy of Sciences: Washington, D. c. (1979).

[23] Maddala, G. S. *Introduction to Econometrics.* New York: Macmillan, 1992.

[24] Mankiw, N. Gregory, David Romer, and David N. Weil, "A Contribution to the Empirics of Economic Growth," *Quart. J. Econ.*107, 2:407-57, 1992.

[25] Newey, W. and K. West, "A Simple Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix," *Econometrica* 55,3:703-08, May, 1987.

[26] Psacharapoulos, George, "Returns to Education: An Updated International Comparison," Mark Blaug (ed.) *The Economic Value of Education: Studies in the Economics of Education.* International Library of Critical Writings in Economics, vol. 17:81-101. Aldershot, U. K.: Elgar (1992)

[27] Ramsey, J. B..,, "Test for Specification Errors in Classical Linear Least Squares Regression Analysis," *J. Royal Stat. Soc.* Series B 31:350-71, 1969.

[28] Said, S. E. and D. A. Dickey, "Testing for Unit Root in ARMA Models of Unknown Order," *Biometrica* 71:599-607, 1980.

[29] Solow, Robert M. "A Contribution to the Theory of Economic Growth," *Quart. J. Econ.* 70, 3:65-94, Feb., 1956.

[30] State Statistical Bureau (SSB), *Quanguo gesheng zishiqu zhixiashi lishi tongji ziliao huibian 1949-1989 (Compilation of provincial economic statistics).* Beijing: Chinese Statistics Press, 1991.

[31] State Statistical Bureau (SSB), *China Statistical Yearbook 1994* and previous years. Beijing: Chinese Statistics Press, 1995 and earlier.

[32] Wang, Guang H., "Technical Change in chinese State Industry: A New Approach," *J. Comp. Econ.* 21,3:308-325 (December, 1995).

[33] Wei, Shang-Jin, *Open Door Policy and China's Rapid Growth: evidence from City-Level Data*, NBER Working Paper No. 4602. Cambridge, MA: National Bureau of Economic Research, December, 1993.

[34] Wolff, Edward N., "Capital Formation and Productivity Convergence Over the Long Term", *Am. Econ. Rev.* 81, 3: 565-79, June, 1991.

[35] Wu, Yanrui, "Productivity Growth, Technological Progress, and Technical Efficieny Change in CHina," *J. Comp. Econ.*21, 2:207-229(October, 1995)

[36] Yang, Dali L. and Houkai Wei, "Rural Enterprise Development and Regional Policy in China," *Asian Perspective* 35, 1, Spring, 1996. (forthcoming).

[37] Young, Alwyn, “A Tale of Two Cities: Factor Accumulation and Technical Change in Hong Kong and Singapore,” *NBER Macroeconomics Annual 1992*. Cambridge, MA: MIT Press, 1992,:15-60