AgEcon SEARCH
RESEARCH IN AGRICULTURAL & APPLIED ECONOMICS

The World's Largest Open Access Agricultural & Applied Economics Digital Library

This document is discoverable and free to researchers across the globe due to the work of AgEcon Search.

Help ensure our sustainability.

Give to AgEcon Search

AgEcon Search
http://ageconsearch.umn.edu
aesearch@umn.edu

*Papers downloaded from **AgEcon Search** may be used for non-commercial purposes and personal study only. No other use, including posting to another Internet site, is permitted without permission from the copyright owner (not AgEcon Search), or as allowed under the provisions of Fair Use, U.S. Copyright Act, Title 17 U.S.C.*

No endorsement of AgEcon Search or its fundraising activities by the author(s) of the following work or their employer(s) is intended or implied.

Available online at www.sciencedirect.com
SCIENCE DIRECT®

ELSEVIER

Agricultural Economics 30 (2004) 89–100

AGRICULTURAL ECONOMICS

www.elsevier.com/locate/agecon

Public investment and regional inequality in rural China

Xiaobo Zhang*, Shenggen Fan

International Food Policy Research Institute (IFPRI), Development Strategy and Governance Division, 2033 K Street, N.W., Washington, DC 20006, USA

Received 8 February 2002; received in revised form 28 August 2002; accepted 11 September 2002

Abstract

This paper develops a method for decomposing the contributions of various types of public investment to regional inequality and applies the method to rural China. Public investments are found to have contributed to production growth in both the agricultural and rural non-agricultural sectors, but their contributions to regional inequality have differed by type of investment and the region in which they are made. All types of investment in the least-developed western region reduce regional inequality, whereas additional investments in the coastal and central regions worsen regional inequality. Investments in rural education and agricultural R&D in the western region have the largest and most favorable impacts on reducing regional inequality.
© 2003 Elsevier B.V. All rights reserved.

JEL classification: D63; O47; R11

Keywords: Public investment; Regional inequality; Growth; Chinese economy

1. Introduction

There has been a long debate on the role of public investment in economic growth (Aschauer, 1989; Barro, 1990; Munnel, 1992; Tatom, 1993; Gramlich, 1994; Holtz-Eakin, 1994; Evans and Karras, 1994; Garcia-Mila et al., 1996). Public investments can be allocated to promote growth directly by providing various public goods, such as research and development (R&D), infrastructure and education, or indirectly by creating an environment to attract private investment. Different public goods have different characteristics and externalities and may, therefore, have different impacts on growth and equity. However, most theoretical and empirical studies focus on either just one type of public investment or on total public investment, and ignore differences between types of public investment. Considering just one type of public investment often leads to overestimation of its returns (Antle, 1988; Griliches, 1988), while using aggregate government investment masks important policy information about which public investments deserve highest priority.

Apart from their role in growth, different types of public investment are also key instruments for governments to use in reducing regional inequality (World Bank, 1994). But except for Martin (1999) and Jacoby (2000), few studies have attempted to investigate both the regional equity and growth impacts of public investments. Jacoby (2000) found that investments in rural roads have a positive impact on growth but an ambiguous effect on regional inequality in rural Nepal. Using a two-region endogenous growth model, Martin (1999) explored the link between road infrastructure and regional inequality. Since both studies

* Corresponding author. Tel.: +1-202-862-8149; fax: +1-202-467-4439.
E-mail address: x.zhang@cgiar.org (X. Zhang).

0169-5150/$ – see front matter © 2003 Elsevier B.V. All rights reserved.
doi:10.1016/j.agecon.2002.09.003

only consider roads, they have limited relevance for policy makers who must choose between different types of investment as well as investment levels.

Understanding the marginal effects of different types of government expenditure is crucial for developing countries to adopt pro-poor growth strategies. Due to budget constraints, significant increases in public investment in rural areas seem unlikely. Therefore, the governments must give greater emphasis to using their public investment resources more efficiently. Reliable information on the marginal effects of various types of spending will help governments to hone future investment priorities to achieve the goals of equity and growth.

In this study, we develop a framework to assess the impact of various forms of public investment on growth and regional inequality using China as an example. The key hypothesis we test is that different types of public investment have different impacts on regional inequality. We consider six major types of public investment in this study: Roads, education, electrification, telephones, irrigation and agricultural R&D. These six types of investment are the major instruments used by the government for growth and poverty reduction. In addition, these measures are readily available at the provincial level and consistently compiled for a reasonably long period.[1]

There are two reasons for our choice of China as an example. First, the Chinese economy has grown rapidly over the past two decades at an average annual rate of about 10% while regional inequality has increased significantly (SSB, 1998). Second, due to huge regional differences in geography and resource endowments, China has made significant public investments in some regions in an attempt to overcome natural constraints and reduce regional inequality. The dramatic increase in regional inequality despite rapid growth and an active public investment strategy in China provide a good test for our hypothesis. Since over 60% of the total population in China is still rural, and since most of the poor are concentrated in rural areas, we focus our study on the rural sector. Although numerous studies attempt to describe and explain China's regional inequality (Lyons, 1991; Tsui, 1991; Yang, 1999; Kanbur and Zhang, 1999), previous studies have not systematically examined the role of public investment in changing regional inequality.

One constraint to assessing the distributional impact of public investment is the lack of a suitable analytical framework to distinguish between the contributions of production factors and public investment to regional inequality. In the literature, inequality is decomposed based on either exogenous population groups or income sources (Shorrocks, 1982, 1984). Since the distributional effect of production factors and public investment cannot be directly analyzed with these frameworks, we develop a new approach based on Shorrocks' decomposition methods. Specifically, we first assume both agricultural and non-agricultural production functions are of Cobb–Douglas form, which implies no interdependence among different types of public investment. After expressing the production function in double log-linear form, we can apply Shorrock's decomposition method.[2]

The paper is organized as follows. Section 2 describes recent trends in growth and regional inequality in China. Section 3 develops our conceptual framework. Section 4 provides our estimates of the agricultural and non-agricultural production functions needed to decompose the sources of regional inequality. A simulation is conducted in Section 5 to evaluate the marginal impacts of public investments on inequality amongst three regions. Section 6 highlights our conclusions and policy implications.

2. Growth and regional inequality in China

During the past two decades, Chinese agriculture has experienced phenomenal economic growth. This rapid growth followed the policy reforms of the early

[1] In a similar study, Zhang and Fan (2000) use county-level production data to analyse regional inequality and find that within-province inequality accounts for about 50% of overall regional inequality and the uneven county distribution of non-farm activities is the major cause. Lacking public investment variables at the country level, Zhang and Fan include only education and rural communications in their analysis, and find that they have important effects on the growth and distribution of the non-farm sector.

[2] The Cobb–Douglas type is a rather restrictive form for a production function since it assumes that there is no interdependence among different types of input. However, under the Cobb–Douglas specification, the logarithmic production value is a summation of linear terms, to which Shorrock's decomposition formulae can be applied.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

1980s and has stimulated numerous studies that analyze its sources (e.g. McMillan et al., 1989; Fan, 1991; Lin, 1992; Fan and Pardey, 1997). Following the traditional growth accounting approach (Solow, 1957; Denison, 1962), most of these studies attempt to analyze the impact of institutional changes in addition to increases in the use of inputs on production growth during the reform period.

Fan and Pardey (1997) were the first to point out that omitted variables such as agricultural R&D investment would bias estimates of the sources of production growth. To address this concern, they included a research stock variable in the production function to account for the contribution of R&D investment to rapid production growth, in addition to inputs and institutional changes. They found that ignoring the R&D variable in the production function leads to a significant overestimation of the impact of institutional change.

In addition to R&D investment, government investment in roads, electrification, education, and other public goods and services in rural areas may have also contributed to rapid growth in agricultural production. Omitting these variables will also likely bias estimates of the production function for Chinese agriculture.

Despite the phenomenal development of the rural non-farm sector in China, very few researchers have analyzed the sources of growth of this increasingly important sector. The only exception is Fan et al. (2002a,b), who decomposed the sources of growth into growth in capital and labor. But they failed to include public investment directly as a source of growth. One of the motivations of this study is to include these public investment variables when estimating the production functions for agriculture and non-agriculture, and to calculate the differential impact of these investments on regional inequality.

Table 1 presents data on six types of government spending from 1978 to 1995. The average annual growth rate of total investment is 8.3%, which is line with the annual growth rate of GDP. The weights of the six types of spending has changed significantly. The share of agricultural R&D expenditure has declined at an annual rate of 3.9%, while government spending on communication has experienced a dramatic increase (11.9% per year). The changes in

Table 1
Public spending in rural China, 1978–1995

Year	Total (billions of 1990 Yuan)	R&D (%)	Irrigation (%)	Education (%)	Roads (%)	Power (%)	Communication (%)	Coast/ non-coast
1978	19.3	5.9	44.5	39.1	3.5	5.4	1.5	0.9
1979	22.4	5.9	44.0	41.0	3.3	4.7	1.2	1.0
1980	21.3	6.1	35.0	50.0	3.2	4.6	1.1	1.0
1981	19.4	6.3	26.8	58.2	2.0	5.5	1.2	1.1
1982	21.3	5.7	26.8	58.5	2.0	5.8	1.2	1.1
1983	23.8	6.4	25.9	58.1	1.9	6.5	1.3	1.1
1984	26.6	6.6	21.8	60.9	1.8	7.3	1.5	1.1
1985	30.2	5.8	17.1	62.9	4.1	8.5	1.5	1.2
1986	35.3	5.0	15.6	63.4	3.9	10.3	1.7	1.3
1987	41.2	4.0	14.9	64.1	3.9	11.0	2.1	1.3
1988	41.9	4.4	14.0	64.4	4.6	10.7	2.0	1.3
1989	37.5	4.7	15.3	61.0	5.5	11.1	2.4	1.3
1990	42.4	3.8	16.9	59.0	6.0	11.7	2.5	1.4
1991	50.1	3.6	19.6	56.9	5.9	11.2	2.8	1.4
1992	62.8	3.4	21.9	51.4	8.3	11.3	3.8	1.6
1993	72.1	3.1	19.9	52.8	5.3	12.0	6.9	1.5
1994	72.4	3.2	18.8	47.9	6.8	12.3	11.1	1.7
1995	74.9	3.0	20.6	45.6	7.6	12.8	10.4	1.7
Annual growth rate (%)	8.3	−3.9	−4.4	0.9	4.6	5.2	11.9	3.7

Source: Fan et al. (2002a,b, p. 19). Total public spending is the sum of the six types of spending listed in the table. The last column is calculated by the authors.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

levels and composition of government spending are likely to affect both regional growth and equity.

Another feature of the Chinese economy is that the gains from the policy reforms have not been evenly distributed across regions. The difference in the growth rates between the coastal and inland regions has been as high as 3% points during the past two decades and regional inequality for China as a whole has increased significantly (Kanbur and Zhang, 1999). Since the late 1970s, China has implemented a coastal development policy. Special zones and open economic areas were enacted in coastal cities and granted tax breaks and other preferential investment policies. As a result, a large portion of foreign direct investment and public investment has been concentrated in the coastal region. As shown the last column in Table 1, the ratio of per capita government spending in the coastal region relative to other regions has increased from 0.9 in 1978 to 1.7 in 1995. It is legitimate to speculate that the skewed distribution of public investment might be an important factor behind the increase in regional inequality.

In order to better analyze these issues, we divide China into three zones: the east or coastal zone which includes Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Guangxi provinces; the central zone comprising Shanxi, Inner Mongolia, Anhui, Jiangxi, Henan, Hubei and Hunan provinces; and the west zone comprising all remaining provinces. Tibet is excluded due to lack of data. Hainan is included in Guangdong Province. Beijing, Shanghai and Tianjin are excluded because of their small share of rural areas and population.

Table 2 compares key characteristics of the three zones in 1978 and 1995, using the western region in 1978 as a base. Labor productivities in the agricultural and non-agricultural sectors were higher in the coastal and central regions than in the western region in 1978. In addition, the productivity gaps between the western and other regions increased significantly between 1978 and 1995. For instance, the difference in agricultural labor productivity between the coastal and western zones rose from 1.03 to 1.76 (2.75/1.56).

Not only has the gap in labor productivity increased, but also has the disparity in input use. For example, the capital–labour ratio for non-agricultural production was 20% higher in the coastal zone than in the western zone in 1978. By 1995, the capital–labour ratio was 116% higher than the level in the western region in 1978, and more than two times higher than the western region's level in 1995. The most notable gap is the difference in the number of rural telephones per rural resident. In 1978, the coastal region had 126% more telephones per hundred households than the western region. In 1995, the gap was more than 40 times the level in the western region in

Table 2
Productivity and public capitals by zone

Year and characteristics	Coastal	Central	Western
1978			
Agricultural GDP/labor	1.03	1.12	1.00
Rural non-agricultural GDP/labor	1.53	1.29	1.00
Capital/labor			
For agricultural production	0.69	0.55	1.00
For non-agricultural production	1.20	1.75	1.00
Road density	2.97	1.93	1.00
Education level	1.79	1.27	1.00
Electrification	1.46	1.45	1.00
Phone (rural communication)	2.26	1.52	1.00
The percentage arable land irrigated	1.54	1.12	1.00
Agricultural R&D per capita	0.40	0.41	1.00
1995			
Agricultural GDP/labor	2.75	2.34	1.56
Rural non-agricultural GDP/labor	12.90	11.49	7.39
Capital/labor			
For agricultural production	1.14	0.99	1.01
For non-agricultural production	2.16	0.92	0.67
Road density	4.88	2.26	1.23
Education level	1.54	1.55	1.25
Electrification	13.83	5.61	4.11
Phone (rural communication)	40.78	9.50	3.91
The percentage arable land irrigated	1.63	1.15	1.12
Agricultural R&D per capita	0.28	0.19	0.36

Note: Authors' calculations. (1) The coastal zone includes the provinces Hebei, Liaoning, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong and Guangxi. The central zone contains Shanxi, Inner Mongolia, Anhui, Jiangxi, Henan, Hubei and Hunan. The remaining provinces are classified as the western zone. Tibet is excluded due to the lack of data. Hainan is included in Guangdong Province. (2) All numbers are expressed as ratios of the corresponding value for the western region.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

1978, and ten times the western level in 1995. Comparing public capital stocks among different regions, only the gaps in education and irrigation levels have narrowed between the coastal and western regions. In comparison, the differences in public capital stocks between the central and western regions have changed rather modestly. It appears that the increased disparity in output levels among regions might have been caused in large part by differences in public investment. However, we need a more formal model to quantify the contributions of various investments on overall inequality.

3. Conceptual framework

We assume that each region has the same agricultural and non-agricultural production functions at a given time but that they lie on different points on the production surfaces. Following standard procedures in the literature, we assume that the agricultural and non-agricultural production functions are of Cobb–Douglas form, with k conventional inputs and m public inputs as follows:[3]

$$Y = A\prod_{i=1}^{k} X_i^{\beta_i}\prod_{j=1}^{m} P_j^{\gamma_j}, \tag{1}$$

where Y is the total gross domestic product (GDP), A the intercept, X_i the conventional inputs such as labor, capital and land, P_j the public investments such as roads and R&D, β_i the output elasticity with respect to conventional input i, and γ_j the output elasticity with respect to public investment j.

The logarithmic form of Eq. (1) is given by

$$y = a + \sum_{i=1}^{k}\beta_i x_i + \sum_{j=1}^{m}\gamma_j p_j + \varepsilon, \tag{2}$$

where lower cases indicate logarithms. An error term (is added to represent stochastic shocks to output and is assumed to be unrelated to the other variables.

[3] Governance varies across regions, which may in turn influence the allocation and efficiency of public inputs. However, due to lack of systematic data to capture this variable, the role of governance is not considered in the model.

Following Shorrocks (1982), the variance of y in Eq. (2) can be decomposed as[4]

$$\begin{aligned}\sigma^2(y) &= \sum_{i=1}^{k}\mathrm{cov}(y, \beta_i x_i) + \sum_{j=1}^{m}\mathrm{cov}(y, \gamma_i p_j) + \mathrm{cov}(y, \varepsilon)\\ &= \sum_{i=1}^{k}\beta_i\,\mathrm{cov}(y, x_i) + \sum_{j=1}^{m}\gamma_j\,\mathrm{cov}(y, p_j) + \sigma^2(\varepsilon),\end{aligned} \tag{3}$$

where $\sigma^2(y)$ is the variance of y and $\mathrm{cov}(y, \cdot)$ represents the covariance of y with other variables. Since all the right-hand side variables in Eq. (2) are not correlated with the error term, the covariance of y and (is equal to the variance of (. Considering that y is in logarithmic form, $\sigma^2(y)$ is a standard inequality measure known as the logarithmic variance (Cowell, 1995). It has the property of invariance to scale. According to Shorrocks (1982), the covariance terms on the right-hand-side of (3) can be regarded as the contributions of the factor components to total inequality.

Using estimates from (2) and applying the decomposition in (3), we are able to quantify the contributions of various public investments to regional inequality in agricultural GDP and non-agricultural GDP. Moreover, it is also possible to calculate the impact of public investment on regional inequality in total GDP. For this purpose, we assume a Cobb–Douglas aggregation over sectors, and then regress the logarithms of agricultural GDP and non-agricultural GDP on the logarithm of total GDP as follows:

$$y = a_1 y_1 + a_2 y_i, \tag{4}$$

where y, y_1, and y_2 are GDP, agricultural GDP, and non-agricultural GDP in logarithms, respectively; and a_1 and a_2 are the elasticities of y_1 and y_2 with respect to y. After estimating y_1 and y_2 based on (2), we can substitute the estimates into the aggregate GDP function (4) and then decompose the contributions of different inputs and investments on inequality in total GDP, again using Eq. (3).

[4] Fields and Yoo (2000) use a similar method to account for labour income inequality in Korea.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

4. Data and empirical results

4.1. Data

A panel data set including 25 provinces over the period 1978–1995 was constructed from various governmental data sources. We divided total rural GDP into agricultural GDP and rural non-agricultural GDP to reflect differences in their underlying production structures. Both nominal GDP and real GDP growth indices for various sectors are available from *the gross domestic product of China* (State Statistics Bureau—SSB, 1997a). The data sources and method of construction of national GDP estimates are published by the SSB (1997b). This publication indicates that the SSB has used the UN standard SNA (system of national accounts) definitions to estimate GDP in Mainland China for the period of 1952–1995. This is the first time that the SSB has published historical GDP information at the provincial level for such a long period of time. We assume prices were the same for all provinces in 1980. Under this assumption, real GDP estimates for the whole period can be derived from nominal GDP data for 1980 and the published annual growth rates in real GDP.

In the empirical analysis, we consider both agricultural and non-agricultural production. Our specification of the agricultural production function includes conventional inputs (land, labor and capital) and public investment goods such as roads, education, irrigation, electrification, rural telephones and agricultural R&D capital generated by government investment. Additionally, we include annual rainfall to reflect regional differences in natural production conditions. Our specification of the non-agricultural production function includes all the same variables except land, irrigation, agricultural R&D and rainfall.

Since the data sources for the above input variables can be found in Fan et al. (2002a,b), we only briefly introduce the definitions of these variables. Labor is measured in stock terms as the number of persons at the end of each year. Capital stocks are calculated based on gross capital formation and annual fixed asset investment and adjusted with appropriate price indices and depreciation rates. Land refers to arable land area. The average years of schooling among the rural population is used as the measure of education. The irrigation variable is expressed as the ratio of irrigated area to total arable land. Roads are measured in density form, i.e. road length in kilometers per thousand square kilometers of geographic area. Electricity and rural telephones are the average electricity consumption and number of rural telephones per rural resident.

R&D is measured in stock form, and is defined as a function of past government expenditures on agricultural R&D. For simplification, we assume that the R&D stock follows a polynomial distributed lag (PDL) of degree 2. Based on available data and econometric tests, the lag length is set at 17 years. This means we only need estimate three parameters to obtain all the parameters of a 17-year lag structure. For additional details on the method, see Davidson and MacKinnon (1993) and Fan et al. (2002a,b).

4.2. Results

Agricultural and non-agricultural GDP functions were estimated based on Eq. (2) and the results are presented in Table 3. For each production function, we present three different specifications: fixed effects, random effects and regional dummy method. In all the specifications, year dummies are included to capture time-specific effects common to all provinces. But the specifications differ in how region-specific effects are dealt with. In the first specification, a standard fixed effects model, all the province dummies are included. The second specification assumes the individual constant terms are randomly distributed across cross-sectional units. In the third specification, only two regional dummies (one is set as default) are included to capture systematic difference across the coastal, central and western regions.

In large because this specification includes more variables than the other two specifications, it has the highest R^2. After adjusting the degree of freedom, the *AIC* shows that the fixed effects model has a better fit than the regional dummy model. However, under this specification, the independent variables are highly correlated to each other. The variable 'road' in particular has a serious problem as shown in the last row with a VIF value of 202 and 169 for agricultural and non-agricultural production functions (a value over 20 indicates the existence of multicollinearity).

The random effects model is less costly in terms of degrees of freedom than the fixed effects model. But it assumes the cross-sectional units are chosen randomly

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 3
Production function estimations

Variables	Agricultural GDP			Rural non-agricultural GDP		
	(1) Fixed	(2) Random	(3) Zone dummy	(1) Fixed	(2) Random	(3) Zone dummy
Labor	0.198* (0.063)	0.431* (0.053)	0.364* (0.042)	0.045 (0.048)	0.222* (0.046)	0.485* (0.042)
Capital	0.030 (0.038)	0.043 (0.033)	0.068* (0.017)	0.250* (0.073)	0.426* (0.061)	0.494* (0.040)
Land	0.028 (0.065)	0.343* (0.050)	0.561* (0.039)			
Roads	0.172* (0.073)	0.081* (0.047)	0.012 (0.026)	−0.669* (0.198)	0.237* (0.097)	0.134* (0.037)
Education	−0.077 (0.084)	0.073 (0.087)	0.340* (0.089)	1.169* (0.244)	0.876* (0.228)	0.324* (0.174)
Electricity	0.014 (0.030)	0.093* (0.028)	0.055* (0.027)	0.291* (0.096)	0.013 (0.078)	0.104* (0.040)
Telephones	−0.007 (0.014)	0.018 (0.014)	0.110* (0.017)	0.212* (0.041)	0.187* (0.041)	0.216* (0.033)
Irrigation	0.023 (0.058)	0.260* (0.044)	0.318* (0.025)			
Research	0.019 (0.020)	0.036* (0.017)	0.032 (0.023)			
Rainfall	0.053* (0.019)	0.082* (0.020)	0.225* (0.027)			
R^2	0.992	0.934	0.969	0.979	0.931	0.951
AIC	−883.21	n.a.	−344.062	92.185	n.a.	437.581
Hausman test (P-value)		0.000			0.000	
VIF for roads	202.48		6.63	168.76		2.62

Note: The data used are from 1978 to 1995. All variables are in logarithms. Year dummies were included in the model. Figures in parentheses are standard errors.
* Statistical significance at 10%.

from a large population and the individual effects are uncorrelated with the other regressors. Because the data set covers all the provinces, it is inappropriate to assume the cross-sectional units are randomly drawn from a larger population. To check the second point of no correlation, we present the Hausman test in the second to last row. The small P-values strongly reject the null hypothesis of orthogonality underlying the random effects model and suggest there are some individual effects. As a compromise, the third specification includes only regional dummies. In so doing, we not only reduce the extent of multicollinearity inherent in the fixed effects model (the largest VIF is below 20), but also to a certain degree capture systematic individual effects as suggested by the Hausman test. We therefore use the third specification as a basis for the inequality decomposition.

Regarding the third specification, most of the coefficients for the year and region dummy variables (which are not reported in the table) are statistically significant. The adjusted R^2's for the agricultural and non-agricultural GDP functions are high at 0.966 and 0.949, respectively, implying good fits. All the coefficients in the estimated agricultural GDP function are positive and, except for roads, statistically significant at the 5% level. The summation of the coefficients for conventional inputs—labor, capital and land, is 0.993, suggesting constant returns to scale. In China, labor is abundant and land is scarce, hence one should expect that the elasticity of land would be larger than that of labor. This is confirmed in Table 3; the elasticity of land is 0.56 while the elasticity of labor is 0.36. The coefficient for irrigation—a land-enhancing technology—is also significant at 0.318. These results are consistent with the induced innovation hypothesis (Hayami and Ruttan, 1985). Because arable land is a rather scarce production factor, land is usually cultivated more intensively to increase yield through land-enhancing technologies, such as irrigation. Among the six types of public investment goods, education and irrigation have the largest and second largest output elasticities. The elasticities for roads and agricultural R&D are relatively small.

Turning to the rural non-agricultural GDP function, all coefficients are significant and positive. The sum of the coefficients for the conventional inputs (capital and labor) is also roughly 1, suggesting that there are no economies or diseconomies of scale. Education is the most significant contributing public investment to rural non-agricultural GDP. Rural telephone services and roads have the second and third largest effects on non-agricultural output, respectively.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

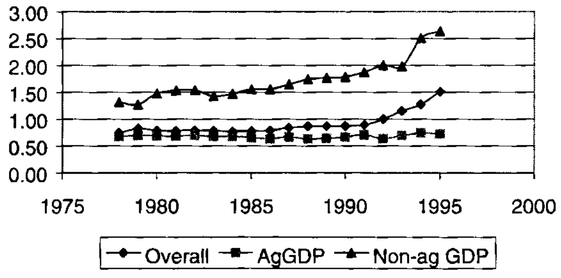

Fig. 1. Regional inequality from 1978 to 1995 (lag variance).

Fig. 1 shows the time paths of regional inequality, measured in log variance, in agricultural GDP rural non-agricultural GDP, and total GDP from 1978 to 1995. Regional inequality in agricultural GDP changed rather modestly from 0.681 to 0.727 over this period, but inequality in non-agricultural GDP doubled from 1.107 to 2.322. Inequality in total GDP doubled from 0.751 in 1978 to 1.510 in 1995, and this was almost entirely due to increased inequality in non-agricultural GDP. This confirms similar findings by Rozelle (1994).

Given the estimated coefficients for the two GDP functions, we can now apply the inequality decomposition method outlined in Eq. (3). Tables 4–6 report the contributions of each factor to regional inequality for agricultural GDP, non-agricultural GDP and total GDP, respectively. The contributions of the three conventional inputs (capital, labor and land) to regional inequality in agricultural GDP have declined, while the contributions of most public investments, especially R&D, electrification, and telephones, have increased (Table 4). Public investment's total contribution to regional inequality in agricultural GDP increased from 0.074 in 1978 to 0.161 in 1995.

The results are similar for changes in regional inequality in non-agricultural GDP (Table 5). Capital and labor have contributed little to growing inequality, while public investment in roads, electricity, telephones and in total has increased regional inequality. Public investment's contribution to regional inequality in non-agricultural GDP increased from 0.139 in 1978 to 0.510 in 1995.

Turning to total GDP, capital's contribution to growing regional inequality increased from 0.070 in 1978 to 0.383 in 1995, even though its shares in the inequality of agricultural GDP and non-agricultural GDP changed little (Table 6). This is probably due to a structural shift in capital from agricultural to non-agricultural production in the economy because rural industry is more capital intensive than

Table 4
Contributions of input factors to regional inequality in agricultural GDP

Year	Inequality	Capital	Labor	Land	Education	Irrigation	Roads	R&D	Electricity	Phones	Public investment
1978	0.729	0.036	0.260	0.226	0.029	0.064	0.005	−0.008	−0.006	0.002	0.086
1979	0.800	0.037	0.270	0.238	0.022	0.071	0.005	−0.008	−0.005	0.005	0.090
1980	0.769	0.038	0.264	0.228	0.019	0.071	0.006	−0.006	−0.005	0.003	0.087
1981	0.748	0.037	0.258	0.233	0.019	0.070	0.005	−0.007	−0.003	0.005	0.090
1982	0.756	0.037	0.260	0.230	0.016	0.072	0.005	−0.006	−0.001	0.004	0.090
1983	0.729	0.035	0.248	0.243	0.018	0.061	0.005	−0.005	0.003	0.002	0.084
1984	0.718	0.035	0.244	0.239	0.019	0.063	0.005	−0.007	0.003	0.001	0.084
1985	0.696	0.035	0.242	0.232	0.018	0.068	0.005	−0.008	0.003	0.000	0.086
1986	0.673	0.034	0.235	0.228	0.020	0.061	0.005	−0.008	0.004	0.001	0.083
1987	0.691	0.033	0.237	0.230	0.022	0.061	0.005	−0.008	0.003	0.001	0.084
1988	0.663	0.032	0.230	0.227	0.027	0.058	0.005	−0.007	0.003	0.004	0.090
1989	0.662	0.031	0.235	0.219	0.025	0.064	0.005	−0.005	0.003	0.002	0.094
1990	0.653	0.030	0.231	0.231	0.028	0.056	0.005	−0.002	0.002	0.005	0.094
1991	0.648	0.029	0.230	0.222	0.029	0.059	0.004	0.001	0.003	0.008	0.104
1992	0.664	0.030	0.230	0.223	0.029	0.056	0.005	0.004	0.004	0.012	0.109
1993	0.668	0.031	0.227	0.223	0.026	0.058	0.005	0.006	0.005	0.008	0.108
1994	0.676	0.032	0.223	0.224	0.028	0.059	0.005	0.006	0.006	0.045	0.149
1995	0.719	0.035	0.227	0.229	0.027	0.062	0.005	0.007	0.009	0.045	0.156

Note: The public investment column is the summation of the columns for education, irrigation, roads, R&D, electricity and telephones.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 5
Contributions of input factors to regional inequality in non-agricultural GDP

Year	Inequality	Capital	Labor	Education	Roads	Electricity	Phone	Public investment
1978	1.102	0.520	0.417	0.034	0.074	−0.005	0.018	0.121
1979	1.130	0.529	0.503	0.026	0.075	0.001	0.025	0.127
1980	1.096	0.528	0.556	0.022	0.072	0.003	0.025	0.121
1981	1.255	0.576	0.611	0.023	0.082	0.009	0.031	0.144
1982	1.269	0.586	0.607	0.021	0.079	0.014	0.032	0.146
1983	1.380	0.620	0.617	0.024	0.084	0.020	0.029	0.159
1984	1.333	0.623	0.598	0.025	0.085	0.021	0.029	0.159
1985	1.417	0.645	0.646	0.028	0.089	0.029	0.035	0.180
1986	1.566	0.689	0.660	0.032	0.096	0.034	0.039	0.200
1987	1.784	0.752	0.713	0.038	0.100	0.038	0.043	0.219
1988	1.940	0.785	0.751	0.047	0.107	0.041	0.059	0.254
1989	1.941	0.794	0.740	0.047	0.107	0.041	0.064	0.259
1990	2.009	0.814	0.754	0.047	0.111	0.037	0.073	0.267
1991	2.033	0.838	0.759	0.047	0.112	0.041	0.086	0.286
1992	2.262	0.913	0.815	0.049	0.122	0.047	0.106	0.324
1993	2.509	0.966	0.869	0.048	0.131	0.050	0.089	0.318
1994	2.581	1.041	0.873	0.051	0.134	0.057	0.245	0.488
1995	2.761	1.012	0.905	0.052	0.143	0.050	0.245	0.490

Note: The public investment column is the summation of the columns for education, roads, electricity and telephones.

agriculture. For the same reason, land and land-enhancing technologies, especially irrigation, which are mainly used in agricultural production, have accounted for a decreasing share of overall inequality. The contributions of roads, agricultural R&D, electricity and telecommunications have increased significantly. All this suggests that public investment has pursued a regionally biased strategy over the past two

Table 6
Contributions of input factors to regional inequality in total GDP

Year	Inequality	Capital	Labor	Land	Education	Irrigation	Roads	R&D	Electricity	Phones	Public investment
1978	0.752	0.070	0.274	0.208	0.030	0.061	0.011	−0.008	−0.006	0.003	0.091
1979	0.822	0.075	0.290	0.219	0.023	0.067	0.011	−0.007	−0.005	0.006	0.094
1980	0.792	0.079	0.291	0.207	0.019	0.067	0.012	−0.006	−0.005	0.005	0.092
1981	0.783	0.079	0.287	0.210	0.019	0.067	0.012	−0.006	−0.002	0.007	0.097
1982	0.796	0.083	0.289	0.208	0.017	0.068	0.012	−0.006	0.000	0.006	0.097
1983	0.783	0.086	0.280	0.216	0.019	0.058	0.012	−0.005	0.004	0.004	0.094
1984	0.774	0.093	0.279	0.208	0.020	0.060	0.013	−0.006	0.004	0.004	0.095
1985	0.780	0.114	0.291	0.192	0.020	0.060	0.016	−0.006	0.006	0.005	0.100
1986	0.790	0.123	0.291	0.187	0.022	0.055	0.017	−0.006	0.008	0.007	0.103
1987	0.844	0.138	0.304	0.187	0.025	0.055	0.018	−0.006	0.008	0.009	0.109
1988	0.869	0.154	0.313	0.181	0.032	0.053	0.020	−0.005	0.010	0.015	0.124
1989	0.870	0.160	0.319	0.175	0.030	0.054	0.021	−0.004	0.010	0.015	0.127
1990	0.878	0.160	0.318	0.183	0.032	0.052	0.021	−0.002	0.009	0.019	0.132
1991	0.898	0.173	0.324	0.173	0.033	0.054	0.022	0.001	0.011	0.026	0.146
1992	1.007	0.215	0.354	0.164	0.035	0.051	0.027	0.003	0.015	0.038	0.168
1993	1.166	0.282	0.396	0.147	0.033	0.049	0.036	0.004	0.019	0.036	0.177
1994	1.286	0.357	0.426	0.132	0.036	0.047	0.043	0.004	0.025	0.118	0.274
1995	1.522	0.394	0.486	0.152	0.040	0.054	0.051	0.006	0.028	0.130	0.309

Note: The public investment column is the summation of the columns for education, irrigation, roads, R&D, electricity and telephones.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

decades. As discussed earlier, the coastal region has enjoyed the most favorable investment policy granted by the central government.

5. Marginal effects of public investment on inequality

Using the estimated coefficients in Table 3 and 1995 values for all relevant variables, we are able to calculate the marginal impacts of different types of public investments on regional inequality. Table 7 reports the percentage changes in regional inequality in agricultural GDP, non-agricultural GDP, and total GDP, as a result of a 1% increase in each type of public investment (measured in physical units) within a particular region. Two results are of special interest. First, additional investments of all types in the western areas reduce regional inequality. Additional education in the western region is much more effective in reducing regional inequality in agricultural, non-agricultural and total GDP than any other investment (with elasticities of −0.218, −0.127 and −0.172, respectively).

Table 7
Changes in regional inequality as a result of additional public investments in each region

Public investment	Coast	Central	Western
Agricultural GDP			
Roads	0.004	0.002	−0.008
Education	0.136	0.081	−0.218
Electricity	0.022	0.013	−0.036
Telephones	0.044	0.026	−0.071
Irrigation	0.127	0.075	−0.203
Agricultural R&D	0.017	0.010	−0.028
Rural non-agricultural GDP			
Roads	0.036	0.016	−0.053
Education	0.088	0.039	−0.127
Electricity	0.028	0.012	−0.041
Telephones	0.059	0.026	−0.085
Total rural GDP			
Roads	0.024	0.012	−0.036
Education	0.116	0.057	−0.172
Electricity	0.027	0.013	−0.041
Telephones	0.056	0.027	−0.083
Irrigation	0.058	0.028	−0.086
Agricultural R&D	0.008	0.004	−0.012

Note: The entries are percent changes in regional inequality as a result of a 1% increase in a type of public investment in a specific region. All calculations take 1995 as the base year.

Irrigation has the second largest impact on regional inequality in agricultural GDP with an elasticity of −0.203. For non-agricultural production, development of the rural telephone system in the western region is another important way of reducing regional inequality.

Second, if the government's current coast-biased development strategy continues, regional disparities will worsen. The positive numbers in the second column of Table 7 indicate that additional public investment of all types in the coastal area will worsen regional inequality. The 1% increases in education, telephones and electricity in the coastal area will lead to 0.116, 0.056, and 0.027% increases, respectively, in overall regional inequality. Compared with the western and coastal regions, the marginal effects of public investment in the central region on inequality are less striking.

We can regress each public investment variable against historical government expenditure data following the method developed by Fan et al. (2002a,b) to obtain a dynamic relationship between the stocks of public goods and past government expenditures. Based on the above information in Table 7 and the estimated stock–expenditure relationships, we can further calculate the marginal impact or regional inequality of an additional 100 Yuan (about US$ 12) of public investment per rural resident in each of the three regions (Table 8).

A positive number in Table 8 implies that increasing public investment in that region will widen regional inequality. The results show large regional variations in the impact of different public investments on regional inequality. Additional investments of all types in the western region reduce regional inequality, whereas additional investments of all types in the coastal and central regions increase regional inequality. Education has the largest impact of any investment and, again, additional investment in the western region reduces regional inequality, whereas additional education investments in the central and coastal regions increase it. Investment in the less developed region not only increases labor productivity there, but also enhances labor mobility across regions both of, which contribute to the reduction in regional inequality. These results are true for agricultural, non-agricultural and total GDP.

Additional investments in rural telephones also have large impacts on regional inequality, and follow much

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Table 8
The marginal impact of public investments by region on regional inequality

Public investment	Coast	Central	Western
Agricultural GDP			
Roads	0.046	0.046	−0.115
Education	2.121	2.761	−8.984
Electricity	0.265	0.316	−0.753
Telephones	2.174	0.811	−0.892
Irrigation	0.722	0.619	−1.278
Agricultural R&D	3.881	3.308	−4.282
Rural non-agricultural GDP			
Roads	1.520	1.267	−2.785
Education	5.267	5.150	−20.189
Electricity	1.330	1.208	−3.293
Telephones	11.255	3.175	−4.108
Total rural GDP			
Roads	0.559	0.515	−1.050
Education	3.809	4.105	−15.002
Electricity	0.708	0.711	−1.794
Telephones	5.885	1.830	−2.206
Irrigation	0.693	0.491	−1.140
Agricultural R&D	0.681	0.397	−2.820

Note: The entries are percentage changes in regional inequality as a result of an additional 100 Yuan (about US$ 12) per capita public investment in a specific region. Calculations are based on the most recent year for which data are available, except for telephones that are based on 1988–1993 averages.

the same pattern as investments in education. In particular, additional investment in rural telephones in the coastal regions has a large inequality enhancing effect. The large marginal effects of telephone are directly related to the fact that telephone investment has a large fixed cost. Once it is in place, the additional marginal cost is very low compared to the benefit. From Table 2, it can be seen that the number of telephones per hundred households there is already much higher in the coastal regions than elsewhere (see Table 2).

6. Conclusions

This paper provides a framework for applying Shorrock's method for decomposing the distributional consequence of various types of public investment on regional inequality. Using a provincial level data set for the period 1978–1995 in rural China, a model was estimated that enables the impacts on regional inequality of different types of public investments in each of three regions to be quantified.

Conventional and public inputs have contributed to growth in both agricultural and non-agricultural production, but have played different roles in contributing to changes in overall inequality. In general, the government has pursued a coast-biased investment strategy, and this has been an important factor contributing to the rapid increase in regional inequality.

Regional variations in the impact of public investments on regional inequality are large. Increasing public investment in the less developed western region will lead to a decline in regional disparity. In contrast, if the government continues to favor the coastal region in its investment strategy, regional disparities will widen further. The magnitude of the impact of different types of public investment differs as well. Among the six types of public investment considered in this paper, additional investments in education and agricultural R&D in the western region are the two most powerful ways of reducing regional inequality.

Prioritizing investment in the less developed region will also have a positive impact on poverty reduction. In China, most poor are concentrated in the western region (Fan et al., 2002a,b). The poor own little physical capital and their most important resources are their own human capital. Therefore building human capital through education in the less developed region will enhance labor productivity and improve workers' mobility to seek better job opportunities, thereby benefiting the vast poor population residing in the region. Because the rural poor depend primarily on agriculture and related activities for their livelihood, output and yields of food staples affect the trend of poverty directly. Increasing investment in agricultural R&D is one of the most efficient ways to boost agricultural productivity, which in turn will help reduce rural poverty. In general, the pro-poor growth investment strategy is not only good for promoting growth but also helps to reduce regional inequality and poverty.

Further research is needed on public investment and regional inequality. One of the most important research topics is why there is under-investment in poor rural areas. An analysis of the political and institutional context of public investments and conditions for efficient provision of public goods and services is much needed to improve the efficiency of public investment. In particular, how can the government design a mechanism

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

(policies, regulations and fiscal systems) to mobilize public resources to invest in rural areas? How to evaluate interdependencies between investments across regions and of different types is another area for future research.

Acknowledgements

The authors would like to acknowledge helpful comments by Peter Hazell and seminar participants at Beijing University, IFPRI and the World Bank.

References

Antle, J.M., 1988. Dynamics, causality, and agricultural productivity. In: Capalbo, S.M., Antle, J.M. (Eds.), Agricultural Productivity: Measurement and Explanation. Resource for the Future, Washington, DC, pp. 332–365.

Aschauer, D., 1989. Is public expenditure productive? J. Monetary Econ. 23, 177–220.

Barro, J.R., 1990. Government spending in a simple model of endogenous growth. J. Polit. Econ. 20 (2), 221–247.

Cowell, F., 1995. Measuring Inequality, 2nd ed. Prentice-Hall/Harvester Wheatsheaf, London.

Davidson, R., MacKinnon, J., 1993. Estimation and Inference in Econometrics. Oxford University Press, New York.

Denison, E.F., 1962. The Sources of Economic Growth in the United States and the Alternatives Before Us. Committee for Economic Development, Washington, DC.

Evans, P., Karras, G., 1994. Are government activities productive? Evidence from a panel of US states. Rev. Econ. Statist. 76 (1), 1–11.

Fan, S., 1991. Effects of technology change and institutional reform on production growth in China agriculture. Am. J. Agric. Econ. 73 (2), 266–275.

Fan, S., Pardey, P., 1997. Research, productivity, and output growth in Chinese agriculture. J. Develop. Econ. 53, 115–137.

Fan, S., Zhang, X., Robinson, S., 2002a. Structural change and economic growth in china. Rev. Develop. Econ. 7 (3), 360–377.

Fan, S., Zhang, L., Zhang, X., 2002. Growth and poverty in rural China: the role of public investments. International Food Policy Research Report No. 125. Washington, DC.

Fields, G., Yoo, G., 2000. Falling labour income inequality in Korea's economic growth: patterns and underlying causes. Rev. Income Wealth 46 (2), 139–159.

Garcia-Mila, T., McGuire, T.J., Porter, R.H., 1996. The effect of public capital in state-level production functions reconsidered. Rev. Econ. Statist. 78 (1), 177–180.

Gramlich, E.M., 1994. Infrastructure investment: a review essay. J. Econ. Lit. 32, 1176–1196.

Griliches, Z., 1988. Productivity puzzles and R&D. J. Econ. Perspect. 2 (4), 9–21.

Hayami, Y., Ruttan, V., 1985. Agricultural Development: An International Perspective. Johns Hopkins University Press, Baltimore.

Holtz-Eakin, D., 1994. Public-sector capital and the productivity puzzle. Rev. Econ. Statist. 76 (1), 12–21.

Jacoby, H., 2000. Access to markets and the benefits of rural roads. Econ. J. 110, 713–737.

Kanbur, R., Zhang, X., 1999. Which regional inequality? The evolution of rural–urban and inland–coastal inequality in China, 1983–1995. J. Comp. Econ. 27, 686–701.

Lin, J.Y., 1992. Rural reforms and agricultural growth in China. Am. Econ. Rev. 82 (1), 34–51.

Lyons, T.P., 1991. Interprovincial disparities in China: output and consumption, 1952–1987. Econ. Develop. Cult. Change 39 (3), 471–506.

Martin, P., 1999. Public policies, regional inequalities and growth. J. Publ. Econ. 73, 85–105.

McMillan, J., Whalley, J., Zhu, L.G., 1989. The impact of China's economic reforms on agricultural productivity growth. J. Polit. Econ. 97, 781–807.

Munnel, A.H., 1992. Infrastructure investment and economic growth. J. Econ. Perspect. 6 (4), 189–198.

Rozelle, S., 1994. Rural industrialization and increasing inequality: emerging patterns in China's reforming economy. J. Comp. Econ. 19 (3), 362–391.

Shorrocks, A.F., 1982. Inequality decomposition by factor components. Econometrica 50 (1), 193–211.

Shorrocks, A.F., 1984. Inequality decomposition by population subgroups. Econometrica 52 (6), 1369–1385.

Solow, R.M., 1957. Technical change and the aggregate production function. Rev. Econ. Statist. 39, 312–320.

SSB (State Statistics Bureau), 1997a. The Gross Domestic Product of China, 1952–1995. Dongbei University of Finance and Economics Press, Dalin.

SSB (State Statistics Bureau), 1997b. Calculation Methods of China Annual GDP. China Statistical Publishing House, Beijing.

SSB (State Statistics Bureau), 1998. China Development Report. China Statistical Press, Beijing.

Tatom, J.A., 1993. Paved with good intentions: the mythical national infrastructure crisis. In: Policy Analysis. Cato Institute, August 12.

Tsui, K., 1991. China's regional inequality, 1952–1985. J. Comp. Econ. 15 (1), 1–21.

World Bank, 1994. World Development Report 1994: Infrastructure for Development. Oxford University Press, New York.

Yang, D., 1999. Urban-biased policies and rising income inequality in China. Am. Econ. Rev. 89 (2), 306–310.

Zhang, X., Fan, S., 2000. The profile of China's regional inequality: the importance of nonfarm sector and public inputs. A Report of Australian Centre for International Agricultural Research (ACIAR) Funded Project on Public Investment in Chinese agriculture.

15740862, 2004, 2, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/j.1574-0862.2004.tb00179.x by University Of Minnesota Lib, Wiley Online Library on [16/12/2024]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License