Factor Market Distortions Across Time, Space and Sectors in China

Loren Brandt, Trevor Tombe and Xiaodong Zhu[1]

September 8, 2011

[1]Brandt and Zhu: University of Toronto; Tombe: Wilfrid Laurier University. Emails: brandt@chass.utoronto.ca, ttombe@wlu.ca, xzhu@chass.utoronto.ca. We thank Abhijit Banerjee, Steve Davis, Martin Eichenbaum, Dong He, Aloysius Siow, Michael Zheng Song, Kjetil Storeslettern, Daniel Yi Xu, Dennis Yang and Shang-Jin Wei for helpful discussions. We have also benefited from comments by seminar participants at Chinese University of Hong Kong, Hong Kong Institute for Monetary Research, Ryerson University, Shanghai University of Finance and Economics, Southwest University of Finance and Economics, University of Toronto, and by participants at the China Economic Summer Institute, European Economic Association Meetings in Oslo, NBER China Working Group Meeting, SED Mini-conference on Misallocation in Ghent, and Tsinghua Workshop in Macroeconomics. Part of this paper's research was done while Xiaodong Zhu was a research fellow at the Hong Kong Institute for Monetary Research and he is grateful to the institute's generous financial support.

Abstract

In this paper we measure the distortions in the allocation of labour and capital across provinces and sectors in China for the period 1985-2007. Most existing studies have measured factor market distortions by using some index of dispersion in individual factor returns. However, the map between these dispersion measures and the efficiency loss due to distortions is not clear, especially when there is more than one factor. In this paper, we measure the factor market distortions as the reduction in aggregate TFP due to distortions and decompose the overall distortions into *between-province* and *within-province inter-sectoral* distortions. For the period between 1985 and 2007, the distortions in factor allocation reduced aggregate TFP by about 30% on average, with the within- and between-province distortions accounting for similar portion of the reduction. Despite the large amount of labour reallocation across provinces, the cost of between-province distortions was relatively constant over the period. The cost of within-province distortions declined between 1985 and 1997, contributing to 0.42% TFP growth per year, but then increased significantly in the last ten years, reducing the aggregate TFP growth rate by 0.73% a year. Almost all of the within-province distortions can be accounted for by the misallocation of capital between the state and the non-state sectors. We provide evidence that the recent increase in capital market distortions is related to the government policies that encourage investments in the state sector at the expense of investments in the non-state sector.

Keywords: China; factor market; distortion; productivity;

1 Introduction

Some of the rapid growth that China has enjoyed the last three decades has likely come from reductions in distortions that we expect to accompany the processes of economic transition and development. The period up through the early to mid-1990s in China is often characterized as one of important barriers and restrictions on resource mobility. In addition to restrictions through the hukou system on the movement (both intra- and inter-provincial) of labour out of the countryside (Chan, Henderson and Tsui, 2008), local protectionism and trade barriers also likely impeded the inter-regional flow of goods (Young, 2000; Poncet, 2003). The likely costs of these distortions were reinforced by those on the flow of capital across regions (Boyreau-Debray and Wei 2005, Dollar and Wei, 2007).

The general presumption is that many of these barriers have been significantly relaxed the last decade and a half. For example, migrant labour flows are now in upwards of 150 million, and there have been significant increases in inter-regional trade accompanying reduction in barriers (Holz, 2009). Things are less certain with respect to the behavior of capital flows, however. Reform in the banking system may be helping to allow a more efficient regional allocation of capital through the inter-bank market and other channels. Possibly offsetting some of this is the fact that a significant amount of investment resources continues to be directed by the state to state-owned firms and activities, e.g. infrastructure, or to activities in which the local state is often a beneficiary, e.g. real estate development through land sales. This suggests significant differences in the returns to capital between the state and non-state, which have recently been documented by Brandt and Zhu (2010)). Since the late 1990s, there have also been efforts, through such policies as the Xibu Kaifa (Develop the Great West), to eliminate perceived policy biases in favour of coastal provinces by reallocating investment resources towards the interior regions.

In this paper, we measure the impact on aggregate TFP of distortions in factor allocation across provinces and sectors in China and investigate the contribution of changes in these distortions to aggregate TFP growth. How should one measure the distortions in factor allocation? Existing studies of China's factor market distortions have used separate measures of dispersion in the individual returns to labour and capital. Boyreau-Debray and Wei (2004), Dollar and Wei (2007), and Bai, Hsieh and Qian (2006), for example, examine the dispersion in returns to capital. Gong and Xie (2006) and Zhang and Tan (2007) look at the dispersions in returns to labour as well as in returns to capital, but separately. While these dispersion measures are informative about factor market distortions, there is no clear link between these measures and the aggregate TFP. In this study, we follow the strategy of Hsieh and Klenow (2009) by examining the overall factor market distortions and linking them to aggregate TFP. More specifically, we measure the impact of factor market distortions as the reduction in aggregate TFP due to the distortions. This approach not only allows us to identify the sources of factor market distortions but also to measure the impact of these distortions on aggregate efficiency in the economy. While Hsieh and Klenow investigate the misallocation of factors across manufacturing firms within four-digit industries, we focus on the distortions in the allocation of factors across provinces and between the state and non-state sectors. Our main results are the following:

- On average, the misallocation of factors across provinces and sectors resulted in around 30% reduction of aggregate TFP, with the within-province distortions accounting for more than half of the total reductions.
- The cost of between-province distortions was relatively constant over the entire period.
- Despite a significant labour reallocation across provinces, the cost of between-province labour market distortions remains high due to increase in cross-province dispersion in TFP.
- The measure of within-province distortions declined sharply between 1985 and 1997, contributing to 0.42% TFP growth per year, but then increased significantly in the last ten years, reducing the aggregate TFP growth rate by 0.73% a year.
- Almost all of the within-province distortions were due to the misallocation of capital between the state and the non-state sectors, which incrased sharply in recent years.

This paper is related to a recent literature that investigates the impact of misallocation of factors, either across sectors, or across firms within sectors or industries, on aggregate productivity. Gollin, Parente and Rogerson (2004), Restuccia et. al. (2008) and Vollrath (2009) analyze the sectoral dimension while Bartelsman et. al (2009), Hsieh and Klenow (2009), Banerjee and Duflo (2008); Restuccia and Rogerson (2008); Alfaro et. al. (2008), and Guner et. al. (2008) focus on the misallocation across firms.

The rest of the paper is organized as follows. In Section 2, we present the theoretical framework for measuring factor market distortions and in Section 3, discuss data used for empirical analysis. We present the empirical results in Section 4 and provide discussions on the main results in Section 5. Finally we extend our analysis by incorporating infrastructure capital in Section 6 and concludes.

2 A Framework for Measuring Factor Market Distortions

Consider an economy with m provinces, indexed by $i = 1, \ldots, m$, and two sectors, state and non-state, indexed by $j = n, s$, respectively. We assume Cobb-Douglas production technologies with constant factor income shares in all provinces and sectors:

$$Y_{ij} = A_{ij} L_{ij}^{a} K_{ij}^{1-a}, \, 0 < a < 1. \tag{1}$$

We also assume that provincial GDP is a CES aggregate of goods produced in the two sectors and the aggregate GDP is a CES aggregate of provincial GDPs. Thus,

$$Y_i = \left(Y_{in}^{1-\phi} + Y_{is}^{1-\phi} \right)^{\frac{1}{1-\phi}} \tag{2}$$

and

$$Y = \left(\sum_{i=1}^{m} Y_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{3}$$

Here ϕ^{-1} and σ^{-1} are the elasticities of substitution among sectors and provinces, respectively. To avoid the result that, without distortions, all factors should be allocated to the province and sector with the highest TFP level, we will assume that the goods across sectors and regions are imperfect substitutes, i.e., positive ϕ and σ.[1]

Let

$$L_i = L_{in} + L_{is}, \, K_i = K_{in} + K_{is}$$

be the employment and capital stock in province i and let

$$l_{j|i} = \frac{L_{ij}}{L_i}, k_{j|i} = \frac{K_{ij}}{K_i}$$

$$l_i = \frac{L_i}{L}, k_i = \frac{K_i}{K}$$

be the shares of employment and capital. Then, the provincial and aggregate TFP can be written as follows:

$$A_i = \left[Y_{is}^{1-\phi} + Y_{in}^{1-\phi} \right]^{\frac{1}{1-\phi}} / (L_i^a K_i^b) = \left[\left(A_{is} l_{s|i}^a k_{s|i}^b \right)^{1-\phi} + \left(A_{in} l_{n|i}^a k_{n|i}^b \right)^{1-\phi} \right]^{\frac{1}{1-\phi}}$$

[1] Alternatively, we could have assumed these goods are perfect substitutes but there are diminishing returns.

$$A = \left[\sum_{i=1}^{m} Y_i^{1-\sigma} \right]^{\frac{1}{1-\sigma}} / \left(L^a K^b \right) = \left[\sum_{i=1}^{m} \left(A_i l_i^a k_i^b \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

So, for a given set of sector-province specific TFPs, A_{ij}, $i = 1, \ldots, m$, $j = n, s$, and given aggregate employment and capital stock, L and K, the provincial and aggregate TFPs are determined by the allocation of labour and capital across sectors and provinces.

2.1 Efficient Allocation

As a benchmark, we first examine the efficient allocation of factors when there are no distortions in the economy. To do so, we consider the following social planner's problem:

$$\max_{L_{ij}, K_{ij}} Y$$

subject to (1), (2), (3) and

$$\sum_{i,j} L_{ij} = L \quad (4)$$

$$\sum_{i,j} K_{ij} = K \quad (5)$$

Then, we have

Proposition 1. *For any given L and K, the allocation of labour and capital that maximizes the aggregate GDP is given by:*

$$\frac{L_{ij}}{L_i} = \frac{K_{ij}}{K_i} = \pi_{j|i},$$

$$\frac{L_i}{L} = \frac{K_i}{K} = \pi_i,$$

where

$$\pi_{j|i} = \left(\frac{A_{ij}}{A_i^*} \right)^{\frac{1-\phi}{1-(1-\phi)(a+b)}} = \frac{A_{ij}^{\frac{1-\phi}{1-(1-\phi)(a+b)}}}{\sum_{j=1}^{n} A_{ij}^{\frac{1-\phi}{1-(1-\phi)(a+b)}}}$$

$$\pi_i = \frac{\left(A_i^*\right)^{\frac{1-\sigma}{1-(1-\sigma)(a+b)}}}{\sum_{i=1}^{m} \left(A_i^*\right)^{\frac{1-\sigma}{1-(1-\sigma)(a+b)}}}$$

and

$$A_i^* = \left[\sum_{j=n,s} A_{ij}^{\frac{1-\phi}{1-(1-\phi)(a+b)}} \right]^{\frac{1-(1-\phi)(a+b)}{1-\phi}}$$

Proof: Available from authors upon request.

Proposition 1 says that to maximize output, the share of capital and labour allocated to a sector and province should equal the TFP share in the sector and province, as defined by $\pi_{j|i}$ and π_i. Under the efficient allocation, it can be shown that A_i^* is the provincial TFP and the aggregate TFP is

$$A^* = \left[\sum_{i=1}^{m} (A_i^*)^{\frac{1-\sigma}{1-(1-\sigma)(a+b)}} \right]^{\frac{1-(1-\sigma)(a+b)}{1-\sigma}}$$

For any given allocation of capital and labour, we can then measure the overall distortion and distortion in a province as the proportional loss in TFPs:

$$D = -ln(A/A^*)$$

$$D_i = -ln(A_i/A_i^*)$$

If we simply want to know how distorted the actual allocation is relative to the efficient allocation, we could use the measures above and stop here. To understand the sources of the distortions, however, we need a model to help us to first identify and then measure the impacts of these distortions.

2.2 Factor Allocation in a Competitive Market with Distortions

An inefficient allocation of factors could be a direct result of factor market distortions or an indirect result of product market distortions. For example, even without factor market distortions, the factors could be inefficiently allocated to a province or sector with low TFP if protection in the product market artificially raises the province or sector's profits and therefore factor returns. We consider three distortions: province-specific output wedges and sector-province specific capital and labour wedges.

2.2.1 Firms' Problem

The profit maximization problem for producing the aggregate GDP, Y, is

$$\max_{Y_i, i=1,\ldots,m} \left\{ P \left(\sum_{i=1}^{m} Y_i^{1-\sigma} \right)^{\frac{1}{1-\sigma}} - \sum_{i=1}^{m} \tau_i^y P_i Y_i \right\}$$

which implies the following first order conditions:

$$\tau_i^y P_i = P \left(\frac{Y_i}{Y} \right)^{-\sigma}, \; i = 1, \ldots, m \tag{6}$$

Here τ_i^y is the "tax" on output produced in province i. Note that even though we call it a tax, it should not be interpreted literally as an output tax. Instead, it should be thought of as a wedge between marginal cost and marginal revenue of using Y_i in aggregate production. The capital and labour taxes below should be interpreted in a similar way.

The profit maximization problem of producing Y_i is

$$\max_{Y_{is}, Y_{in}} \left\{ P_i \left(Y_{is}^{1-\phi} + Y_{in}^{1-\phi} \right)^{\frac{1}{1-\phi}} - P_{is} Y_{is} - P_{in} Y_{in} \right\}$$

and the corresponding first-order conditions are

$$P_{ij} = P_i \left(\frac{Y_{ij}}{Y_i} \right)^{-\phi}, \; j = s, n; \; i = 1, \ldots, m \tag{7}$$

Note that we have assumed that there is no sector-specific output tax. We make this assumption because we do not have data to separately identify the taxes. However, the allocation of factors across sectors may still be distorted because wedges in factor markets.

Using the definition of Y_i and Y, it can be shown that

$$P_i = \left(P_{is}^{\frac{\phi}{\phi-1}} + P_{in}^{\frac{\phi}{\phi-1}} \right)^{\frac{\phi-1}{\phi}} \tag{8}$$

and

$$P = \left(\sum_{i=1}^{m} \widehat{P}_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{9}$$

Here,

$$\widehat{P_i} = \tau_i^y P_i. \tag{10}$$

The stand-in firm's profit maximization problem in province i and sector j is

$$\max_{K_{ij},L_{ij}} \left\{ P_{ij}A_{ij}L_{ij}^{a}K_{ij}^{1-a} - \tau_{ij}^{l}wL_{ij} - \tau_{ij}^{k}rK_{ij} \right\}$$

Here, w is the wage and r is the rental price of capital, and τ_{ij}^{l} and τ_{ij}^{k} are taxes on labour and capital, respectively. The standard first-order conditions of the problem are:

$$aP_{ij}A_{ij}L_{ij}^{a-1}K_{ij}^{1-a} = \tau_{ij}^{l}w \tag{11}$$

$$(1-a)P_{ij}A_{ij}L_{ij}^{a}K_{ij}^{-a} = \tau_{ij}^{k}r \tag{12}$$

Definition. *For any given set of taxes* $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\ldots,m;j=n,s}$, *the* ***competitive equilibrium*** *is a set of prices* $\{P, P_i, P_{ij}\}_{i=1,\ldots,m;j=n,s}$, *output* $\{Y, Y_i, Y_{ij}\}_{i=1,\ldots,m;j=n,s}$, *employments* and capital stocks $\{L_{ij}, K_{ij}\}_{i=1,\ldots,m;j=n,s}$ *such that equations (1) to (12) hold. The corresponding set of shares of employment and capital stock* $\{l_i, k_i, l_{j|i}, k_{j|i}\}_{i=1,\ldots,m;j=n,s}$ *is called the* ***competitive allocation implemented by the set of taxes*** $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\ldots,m;j=n,s}$.

Proposition 2. *(1) For any set of positive taxes* $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\ldots,m;j=n,s}$, *the competitive allocation implemented by the set of taxes exists and is unique. (2) For any allocation* $\{l_i, k_i, l_{j|i}, k_{j|i}\}_{i=1,\ldots,m;j=n,s}$, *there exists a set of taxes such that the allocation is the competitive allocation implemented by the set of taxes. (3) Two sets of taxes* $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\ldots,m;j=n,s}$ *and* $\{\theta_i^y, \theta_{ij}^l, \theta_{ij}^k\}_{i=1,\ldots,m;j=n,s}$ *implement the same allocation if and only if there exists some positive constants,* α, β *and* γ *such that* $\theta_i^y = \alpha\tau_i^y$, $\theta_{ij}^l = \beta\tau_{ij}^l$ *and* $\theta_{ij}^k = \gamma\theta_{ij}^k$.

Proof: Available from authors upon request.

2.3 Identification of Distortion Taxes

Proposition 2 shows that we can identify the distortion taxes (up to a proportional constant) from the actual allocation of labour and capital in the economy.

More specifically, from equation (11) and (12), we have

$$\tau_{ij}^{l} \propto \frac{P_{ij}Y_{ij}}{L_{ij}} \tag{13}$$

$$\tau^k_{ij} \propto \frac{P_{ij}Y_{ij}}{K_{ij}} \tag{14}$$

From Proposition 2 we know that factor allocation is not affected by any proportional change in taxes that is common across all province and sectors. So we can simply set the labour and capital taxes as average value products of labour and capital, respectively. These labour and capital taxes ensure that the model implied within-province allocation of labour and capital matches that in the data.

Given the labour and capital taxes, we then identify the output taxes by choosing τ^y_i such that the model implied employment share of province i matches that in the data.[2]

3 Data

In order to generate measures for the Chinese economy of distortions in factor allocation derived above, data at the province-level for both the state and non-state non-agricultural sector are required. Unfortunately, the NBS (National Bureau of Statistics) does not provide information for all the key variables we need, and for others there are a host of measurement issues. Consequently, we construct our own unique panel data set that spans the period between 1985 and 2007 and covers 27 provinces.[3] This section highlights key procedures and sources.[4]

3.1 Employment

The NBS reports employment totals at the province level, with breakdowns provided between agriculture (primary) and non-agriculture (non-primary) and state and non-state.[5] There are several important shortcomings with the official data. First, the provincial employment estimates do not aggregate to reported national employment. Second, provincial employment estimates often include migrants in their province of residence (or hukou) rather than in the province in which they work. By 2005, the migrant population exceeded 150 million. Third, employed persons include those unemployed. Fourth, employment in the primary (non-primary) sector is likely overstated (under-stated). And fifth, employment in the state sector is not reportedly consistently.

[2]It can be shown that under the chosen output taxes, the model's implied share of capital stock of province i also matches that in the data.

[3]Chongqing is merged with Sichuan; Tibet, Hainan, and Hunan are excluded for missing data; 1978-1984 contains certain missing observations for certain provinces (Tianjin and Inner Mongolia, mainly) and so results will be displayed only for the 1983-2007 period.

[4]Tables of raw data are provided in an appendix to this paper that will be made available upon request.

[5]"Employed persons" is distinct from "staff and workers," which only cover urban workers.

We use census micro-data records from 1982, 1990, 1995, 2000, and 2005 to deal with the first three problems.[6] Differences between total provincial employment and reported national employment are distributed amongst provinces in a manner consistent with the distribution of employment found in the census. Next, we utilize alternative estimates of the share of the labour force in the primary sector made by Brandt and Zhu (2010) to adjust official provincial primary employment.[7] Finally, from 1993 onwards, we include employment in shareholding corporations in the state sector.

Note that all adjustments to provincial employment data, with the exception of that to provincial state sector employment, are effectively adjustments to employment in the non-state sector. In other words, we take state sector (and shareholding) employment as officially reported, and calculate non-state sector employment as the residual from our revised estimates of employment in the non-primary sector after subtracting off the broadly defined state employment. It is widely agreed that the NBS does a much better job of collecting data in the state sector than it does outside.

3.2 Capital Stocks

We construct capital stock estimates with a perpetual inventory method using annual fixed investment data reported by the NBS. These data are reported by province, and with breakdowns between primary and non-primary, and state and non-state. After 1993, fixed investment by shareholding companies is reported separately, and added to that by the state sector.[8] Investment data are deflated using official province-level price indexes of investment goods for the period 1993-2007. Prior to 1993, however, such provincial data are not available. Instead, we construct an out-of-sample forecast of principal asset deflators based on a regression of provincial asset price deflators on GDP deflators, the national asset price index, and year and province fixed effects.

Assuming a depreciation rate of 7%, investment growth rates over the life of a province are used to generate initial capital values for 1978.[9] These totals are rescaled proportionately across

[6]Data are interpolated between census years. Rates of growth for 1982 to 1990 are used to project estimates back to 1978, while data between 2000 and 2005 are used to forecast totals for 2006 and 2007.

[7]Specifically, the correction factor applied to each province is based on the ratio of reported national reported primary sector employment share relative to the share in Brandt and Zhu (2010) arrived at through household-level surveys. Province-specific adjustment factors would be ideal but we lack appropriate data.

[8]Minor adjustments are made, such as including shareholding corporation investment (post-1993) and limited liability investment (post-2005). These subcategories of investment are found in the Fixed Asset Investment Yearbooks of China.

[9]All provinces have an initial year of 1978, except for Tibet and Chongqing, which begin in 1992 and 1996, respectively.

provinces so that the total state and non-state capital stocks equal the total national levels as determined by Brandt and Zhu (2010). Our estimates of annual real fixed investment are then used to calculate capital stock in subsequent years.

3.3 GDP

Province-level GDP statistics by ownership prove the most challenging. We begin with total non-primary GDP as reported by the NBS – deflated using official province-specific GDP deflators. Within non-agriculture however, the NBS does not provide a complete breakdown for GDP between the state and non-state sectors. Following the methodology of Brandt and Zhu (2010), we assume that relative output-per-worker is identical to relative wages. This implies that each sector's share of non-primary GDP is identical to their share of the total wage bill. Detailed wage data for state and non-state sectors, including township and village enterprises, are used to construct estimates for relative wages.[10] For those sub-components of non-agriculture GDP for which the NBS provides a breakdown between the state and non-state sectors, our method tracks the behaviour of sector GDP reasonably well.

4 Empirical Analysis

4.1 Parameter Choices

There are three parameters in the model: output elasticity a, and the inverse of elasticity of substitution of output across provinces and between sectors, σ and ϕ.

Brandt and Zhu (2010) report that the labour share in China is around 0.5. Due to the factor market distortions, however, labour share is in general not the same as the output elasticity of labour. We follow Hsieh and Klenow (2009) by assuming that the technology parameter is the same as that in the US and set the output elasticity of labour a to 0.67.

There is no available estimate of ϕ and σ in the literature. We choose 0.67 as the value for both parameters. This implies that the elasticity of substitution across provinces and between sectors are both 1.5, which is the value commonly used in the international real business cycle literature

[10]labour Statistics Yearbook of China and the Statistical Yearbook of China, for the period 1993-onwards. Total and state-sector employment and wages, by province, for years prior to 1995 are found in China Regional Economy Statistics.

and is much lower than the values that are used in the trade literature. (See, e.g., Ruhl, 2008.) We choose this low value of elasticity to be on the conservative side in our estimate of distortions. With higher values for these elasticities (and therefore lower values for ϕ and σ), the estimated distortion in China would be larger.

We will also report results when we use alternative values of a, ϕ and σ. As it turns out, our main results are robust to the choices of parameter values.

4.2 Measuring TFP by Province and Sector

To measure distortions, we need to have measures of province-sector specific TFP A_{ij} for all provinces and sectors. To measure this directly, we need to have province and sector specific deflators. However, we only have deflators by province. Furthermore, the provincial deflators are all normalized to one in 1978, which means that the real provincial GDPs may also reflect differences in prices in 1978. So, we need to adjust for both the initial provincial price differences and the sectoral price differences in each year. Let $Y_{ij}^{\text{measured}}(t)$ and $Y_{ij}(t)$ be the measured and actual real GDP for province i and sector j in year t. Then, we have

$$Y_{ij}^{\text{measured}}(t) = \frac{P_{ij}(t)Y_{ij}(t)}{(P_i(t)/P_i(1978))}.$$

So,

$$Y_{ij}(t) = \frac{Y_{ij}^{\text{measured}}(t)}{\left(P_{ij}(t)/P_i(t)\right)P_i(1978)}.$$

Using a method similar to Hsieh and Klenow (2009), we infer the price information from nominal GDP shares. With the CES aggregate production functions, it can be shown that the prices satisfy the following equations:

$$P_{ij}(t)/P_i(t) = \left(\frac{Y_{ij}^{\text{nominal}}(t)}{Y_{is}^{\text{nominal}}(t)+Y_{in}^{\text{nominal}}(t)}\right)^{-\frac{\phi}{1-\phi}}$$

and

$$P_i(1978)/P(1978) = \left(\frac{Y_i^{\text{nominal}}(1978)}{Y^{\text{nominal}}(1978)}\right)^{-\frac{\sigma}{1-\sigma}}$$

Here, $P(1978)$ and $Y^{\text{nominal}}(1978)$ are the national price index and nominal GDP, respectively. We normalize the national price index in 1978 to one. Then, we can calculate the real GDP in the following way[11]:

$$Y_{ij}(t) = Y_{ij}^{\text{measured}}(t) \left(\frac{Y_{ij}^{\text{nominal}}(t)}{Y_{is}^{\text{nominal}}(t) + Y_{in}^{\text{nominal}}(t)} \right)^{\frac{\phi}{1-\phi}} \left(\frac{Y_i^{\text{nominal}}(1978)}{Y^{\text{nominal}}(1978)} \right)^{\frac{\sigma}{1-\sigma}}$$

Figure 1 shows non-agricultural TFP of the state and the non-state sectors for each of the 27 provinces. As can be seen, the TFP levels in the non-state sector are generally higher than those in the state sector and the gaps have increased over time. There are also significant differences in TFP across provinces. Given these differences, it is clear that the allocation of capital and labour across provinces and sectors has important impacts on the aggregate TFP.

4.3 The Evolution of Factor Market Distortions Over Time

We now examine the impact of misallocation of factors on aggregate TFP. Figure 2 plots the actual and efficient aggregate TFP, A and A^*, respectively. Throughout the period between 1985 and 2007, there is a persistent and significant gap between the actual and efficient TFP, suggesting that there has been persistent misallocation of factors in China. Using our measure of distortions, $D = ln(A^*/A)$, the average level of factor market distortions for the entire period is 0.28. In other words, on average the actual TFP is around 30% lower than the efficient TFP. The gap between the actual and efficient TFP narrowed in the first decade or so, but widened afterwards. Correspondingly, the measured level of factor market distortions was 0.31 in 1985, 0.26 in 1997 and 0.33 in 2007. Table 1 shows the growth rates of the efficient and actual TFP for the entire period and two sub-periods, 1985-1997 and 1997-2007. Between 1985 and 1997, the actual annual TFP growth rate was 0.42% higher than the growth rate of the efficient TFP. In other words, there were improvements in factor allocation in the first sub-period and their contribution to aggregate TFP growth was nearly half a percent a year. In the last decade, however, the average annual growth rate of the actual TFP was 0.73% lower than that of the efficient TFP, implying that overall factor market distortions increased during the last decade, more than offsetting all the efficiency gains from reduced distortions in the first sub-period.

To see if the results above are robust to choices of parameter values, Table 2 reports both the average level of distortions and the impact of the change in distortions on the difference between

[11]Note that when $\phi = \sigma = 0$, the case of perfect substitution, the actual GDP is simply the measured GDP and therefore, the measured TFP is also the actual TFP. For the cases of imperfect substitution, however, the two are not the same.

the efficient and actual TFP growth rates for the benchmark case reported above (i.e., $\sigma^{-1} = 1.5$, $\phi^{-1} = 1.5$ and $a = 0.67$) and three other cases: (1) $\sigma^{-1} = 3$, (2) $\phi^{-1} = 3$, and (3) $a = 0.5$, respectively. In all cases, the growth rate of actual TFP is higher than that of efficient TFP for the period between 1985 and 1997, but lower than that of efficient TFP for the period between 1997 and 2007. So, the trend in our measure of distortions is robust to the alternative parameter values.

4.4 Evaluating the Impacts of Within- and Between-Province Distortions

Next, we investigate the impacts of different types of distortions on the aggregate TFP by conducting a series of counterfactual experiments in the model presented in Section 3. To evaluate the impact of within-province distortions in capital allocation, for example, we conduct a counterfactual experiment in the model by setting the capital taxes of both the state and non-state to the average tax of the two sectors within each province. We then compare the resulting measure of the aggregate distortion to the original measure. The difference can be interpreted as the contribution of the within-province misallocation of capital on aggregate TFP.

The counterfactual experiments that we conduct are listed below:

- Within-province:
  - No within-province distortion in capital allocation: Eliminating the within-province difference in capital returns by equalizing the taxes between the state and the non-state sector for capital only.
  - No within-province distortion in labour allocation: Eliminating the within-province difference in labour returns by equalizing the taxes between the state and the non-state sector for labour only.
  - No within-province distortion: The combination of the two above.
- Between-province:
  - No between-province product market distortion: Eliminating the cross-province differences in output taxes.
  - No between-province distortion in capital allocation: Eliminating the cross-province differences in capital taxes.
  - No between-province distortion in labour allocation: Eliminating the cross-province differences in labour taxes.
  - No between-province distortion: The combination of all three above.

Let A_{nw} and A_{nb} be the aggregate TFP when there is no within- and no between-province distortion, respectively. We can define our measure of between-province distortions and within-province distortions, respectively, as

$$D_b = ln(A^*/A_{nw}) \quad \text{and} \quad D_w = ln(A^*/A_{nb}).$$

The former measures the aggregate distortion when all within-province distortions are eliminated and the later measures the aggregate distortion when there is no between-province distortion. Figure 3 plots D_b (no within) and D_w (no between) over time. Eliminating within-province distortions or between province distortions results in a significant reduction in the measure of distortions. However, eliminating the between province distortions does not change the time pattern of the aggregate distortion. In contrast, eliminating within-province distortions leaves the aggregate distortion relatively stable over time, suggesting that the changes in overall distortion over time were mainly due to changes in within-province distortions. As a comparison, we use the same method to measure the between-state distortions in the US and plot the measures over time in Figure 4. While the average between-province distortion in China is 16% between 1985-2007, the measure of the between-state distortions in the US has been close to zero for all years since around 1970.

To quantify the contribution of between- and within-province distortions to aggregate distortion, we use the following two measures:

$$d_b = ln(A_{nb}/A) \quad \text{and} \quad d_w = ln(A_{nw}/A).$$

Figure 5 displays the contributions of between and within-province distortions over time. The former is roughly constant, and the later exhibits a V-shape.

4.4.1 Within-Province Distortions

Distortions within a province take the form of labour or capital market distortions between the state and nonstate sectors. Let A_{nwl} and A_{nwk} be the aggregate TFP when there is no within-province labour and capital market distortion, respectively. We use

$$d_{wl} = ln(A_{nwl}/A), \quad \text{and} \quad d_{wk} = ln(A_{nwk}/A)$$

as measures of the contribution to aggregate distortion of within-province labour and capital market distortions, respectively. Figure 6 display these measures along with the measure d_w over time.

Clearly, most of the contribution of within-province distortions comes from the misallocation of capital between the state and the non-state sector. Furthermore, the time variation in the contribution of within-province distortions to aggregate distortion also comes from the time variation in the contribution of the within-province capital market distortions. The contribution of within-province labour market distortions has been modest and relatively stable over time.

4.4.2 Between-Province Distortions

We can also decompose the between-province distortions into labour, capital and product market distortions. Let A_{nbl}, A_{nbk}, and A_{nby} be the aggregate TFP when there is no between-province labour, capital and product market distortion, respectively. We use

$$d_{bl} = ln(A_{nbl}/A), \quad d_{bk} = ln(A_{nbk}/A), \quad d_{by} = ln(A_{nby}/A)$$

as measures of the contribution to aggregate distortion of between-province labour, capital and product market distortions, respectively. Figure 7 plots these measures over time along with the measure d_b. In contrast to the within-province results, the contribution of between-province capital market distortions has been very small and declining over time. Between-province labour market distortions is the most important source of between-province distortions, followed by the between-province product market distortions.

4.5 Summary of Empirical Results

For the period 1985-2007, we find that factor market distortions reduced the aggregate TFP by about 30%. The cost of the distortions declined until mid-1990s, then rose afterward. Contributions of between-province and within-province distortions are of comparable magnitude. The cost of between-province distortions is roughly constant for the entire period and mostly comes from wedges in labour markets. In contrast, the cost of within-province distortions varies over time, declining between 1985 and 1997, then rising sharply after 1997. Nearly all within-province distortions are due to wedges in capital markets.

Perhaps the most important result from our empirical analysis above is regarding the misallocation of capital between the state and non-state sectors. This distortion accounts for most of the within-province distortions and, more important, almost all the time variation in the impact of distortions. Also noteworthy is that, despite a large amount of cross-province labour reallocation over the years (as evidenced by more than 150 million accumulated migrant workers), the cost of between-province labour market distortions has remained remarkably stable over time. Why has the cost of labour market distortions not declined? What drives the changes in capital market distortions? We turn to addressing these questions in the next section.

5 Discussions

5.1 Why No Decline in Between-province Labour Market Distortions?

As we discussed above, in recent years there have been over 150 million workers reallocated across provinces, most of them going from low TFP (middle and western) provinces to high TFP (coastal) provinces. One expects such reallocation would have reduced the differences in returns to labour across provinces and therefore the between-province labour market distortions. Yet, the cost of between-province labour market distortions has not declined. One explanation for this result is the rising dispersion in TFP across provinces. As the differences in TFP between provinces increase, more labour should be reallocated to the more productive provinces in order to reduce the differences in labour returns. Figure 8 plots the cross-province standard deviation of ln(TFP) over time. In recent years, as the cross-province labour reallocation increased, the cross-province dispersion in TFP has also increased. Whether the differences in returns to labour would increase or decrease depends on the relative speed of the two changes. Our empirical result suggests that the reallocation of labour was not fast enough to offset the rising dispersion in TFP. Consequently, the cost of labour market distortions remained high despite the large amount of labour reallocation.

5.2 What Drives the Changes in Capital Market Distortions?

Figure 7 shows that the between-province capital distortions have declined over time. This suggests that it has been much easier to move capital than move labour across provinces. Moving capital between the state and non-state sectors within provinces, however, has become harder in recent years. Why? Here we provide some evidence showing that it may be a product of the Chinese government's regional policies.

Figure 9 shows the average output per worker for China's four geographical regions: East, Middle, Northeast and West. In 1997, among the four regions, the Eastern region, which includes all the coastal provinces, had the highest labour productivity and the Western region's labour productivity was the lowest. Around that time, many economists and policy makers argued that this disparity in performance was mainly due to the central government's preferential policies towards the Eastern provinces that allowed these provinces to attract more investment. To reduce the disparity, it was argued, the central government should adopt policies that would direct more investments to the Western provinces, which had the lowest labour productivity among the four regions. Thus, a policy initiative called Develop the Great West was introduced by the central government in the late 1990s.

In reality, was the lack of development in the Western region a result of capital scarcity? The answer is no. Figure 10 shows that the Western region actually had the highest capital-output ratio among the four regions. The Develop the Great West policy worked in one aspect: significant increase in the Western region's capital-output ratio between 1997 and 2007. However, it failed to accomplish its stated objective of reducing regional income disparity: Between 1997 and 2007, the disparity in labour productivity between the Western and Eastern regions increased, not decreased. Why the increase in disparity despite the increase in capital intensity in the West? Because most of the increased investment was directed to the region's state sector, which had much lower TFP than that of the non-state sector. (See Figure 11 and 12 for TFP and capital-output ratio by sector and region.) Thus, misallocation of capital between the state and the non-state sector worsened as as result of the regional development policy. Table 3 shows the average impact of the increased within-province misallocation of capital on provincial TFP growth for the four regions during the period of 1997-2007. It is negative for all four regions. However, within-province misallocation of capital had the largest negative impact on TFP growth in the Western region, reducing potential TFP growth rate by 0.87% a year, and the smallest impact in the Eastern region, reducing potential TFP growth rate by 0.51% a year. It is also interesting to notice that prior to mid-1990s the within-province allocation of capital was improving, with the state sector's capital intensity declining from 1987 to 1997 in all four regions.[12] Unfortunately, this trend was reversed in the last 10 years as a result of the government policies that encourage more investments in the state sector at the expense of investments in the non-state sector.

[12] See Brandt and Zhu (2000) for a discussion about the decentralization process that facilitated the movement of capital form the state to non-state sector during this period.

6 Incorporating Infrastructure Capital

In recent years, an increasing portion of the state sector's investments have gone to infrastructure. It is possible that these infrastructure investments have helped to increase the output in the non-state sector and the total returns to these investments have not been fully captured by the output in the state sector. If this is the case, we may have over estimated capital market distortions, especially in recent years. To deal with this issue, we now consider a modification of our benchmark model that incorporates infrastructure capital into our analysis.

For each province, we break down capital in the state sector into infrastructure and non-infrastructure capital and denote them by X_i and K_{is}, respectively. We modify the production functions for both the state and the non-state sectors to include infrastructure capital as an input:

$$Y_{ij} = A_{ij} L_{ij}^{a} K_{ij}^{b} X_i^{1-a-b}$$

We assume that the allocation of infrastructure capital across provinces $(X_1, ..., X_m)$ is determined by the government. For any given allocation of infrastructure capital, we can define the competitive equilibrium with wedges and measures of TFP and distortions in ways that are similar to what we did in Section 3.[13]

Figure 6 plots the infrastructure's share of total capital stock for each of the four regions in China. Notice that the most productive region, East, actually has the lowest infrastructure share. In contrast, the least productive region, West, has the highest infrastructure share. While the share was fairly stable throughout the period between 1978 and 2007 for the Eastern region, it declined initially and then increased in recent years in the Western regions. The timing of the increase also coincides with the implementation of the Develop the Great West policy.

In this model, it can easily be shown that if the government chooses the allocation of infrastructure capital optimally to maximize aggregate output, then the infrastructure share in each province should be given by the following formula:

$$\frac{X_i}{K_i} = \frac{1-a-b}{1-a},$$

where $K_i = K_{is} + K_{in} + X_i$ is the total capital stock in province i. This equation gives us a way to choose the value for parameter b: We first set the same values as in Section 4 for a, σ and ϕ, and then set b=0.25 so that the optimal fraction of capital used for infrastructure match the average

[13]The details of the infrastructure model is available from authors upon request.

fraction in the data.

Given these parameter choices, we can then calculate our measures of distortions and the contributions of various distortions to the aggregate distortion in the same way as we did in Section 4. Figures 14 to 17 plot these measures over time. Because the breakup of capital stock into infrastructure and non-infrastructure capital, the output elasticity of non-infrastructure capital is smaller before. As a result, the contribution of capital market distortions is lower and the contribution of labour market distortions is higher than in the case with no infrastructure capital. However, two main results from section 4 remains to be true here: (1) The cost of between-province labour market distortions is significant and relatively stable over time; and (2) the cost of within-province capital market distortions is also significant and increased in recent years.

7 Conclusion

In this paper, we examine the impact of the misallocation of resources across provinces and sectors (state versus non-state) on aggregate TFP. Despite significant increases in factor mobility, our analysis suggests that China continues to suffer high costs arising from factor market distortions. Even as late as 2007, these distortions were lowering aggregate TFP by a third; alternatively, aggregate TFP would increase by a half without these distortions. Within province distortions arising from the favored treatment of the state-sector vis-a-vis the non-state are most important. After declining during the first decade and a half of reform, these distortions have increased significantly since 1997. There is also a marked "regional" dimension to them, with the distortions and their costs more severe in the central and western provinces. A case can be made that much of this is related to the central government's efforts to redistribute resources to these provinces through a highly inefficient state sector. With the opportunities for future increases in output on the extensive margin narrowing rapidly, these costs on aggregate TFP are likely to take on added importance.

References

[1] Alfaro, Laura, Andrew Charlton and Fabio Kanczuk (2008). "Plant-Size Distribution and Cross-Country Income Differences." NBER Working Paper No. 14060.

[2] Bai, Chong-En, Chang-Tai Hsieh and Yingyi Qian (2006). "The Returns to Capital in China." *Brookings Papers on Economic Activity* 37 (2): 61-102.

[3] Banerjee, Abhijit and Esther Duflo (2008). "Do Firms Want to Borrow More? Testing Credit Constraints Using a Directed Lending Program." MIT Department of Economics Working Paper No. 02-25.

[4] Bartelsman, Eric J., John Haltiwanger and Stefano Scarpetta (2009). "Cross-Country Differences in Productivity: The Role of Allocation and Selection." NBER Working Paper No. 15490.

[5] Boyreau-Debray, Genevieve and Shang-Jin Wei (2005). "Pitfalls of a State-Dominated Financial System: The Case of China?" NBER Working Paper No.11214.

[6] Boyreau-Debray, Genevieve and Shang-Jin Wei (2004). "Can China Grow Faster? A Diagnosis on the Fragmentation of the Domestic Capital Market." IMF Working Papers 04/76, International Monetary Fund.

[7] Brand, Loren and Xiaodong Zhu (2000). "Redistribution in a Decentralizing Economy: Growth and Inflation Cycles in China." *Journal of Political Economy* 108 (2): 422-439.

[8] Brandt, Loren and Xiaodong Zhu (2010). "Accounting for China's Growth." University of Toronto Working Paper No. 394.

[9] Chan, Kam Wing, J. Vernon Henderson and Kai Yuen Tsui (2009). "Spatial Dimensions of Chinese Economic Development." in Loren Brandt and Thomas G. Rawski ed. *China's Great Economic Transformation.* Cambridge University Press: New York.

[10] Dollar, David and Shang-Jin Wei (2007). "Das (Wasted) Kapital: Firm Ownership and Investment Efficiency in China." NBER Working Paper No. 13103.

[11] Gollin, Douglas, Stephen L. Parente and Richard Rogerson (2004). "Farm Work, Home Work, and International Productivity Differences." *Review of Economic Dynamics* 7 (4): 827-850.

[12] Gong, Liutang and Danyang Xie (2006). “Factor Mobility and Dispersion in Marginal Products: A Case on China.” *Frontiers of Economics in China* 1: 1-13.

[13] Guner, Nezih, Gustavo Ventura and Yi Xu (2008). “Macroeconomic Implications of Size Dependent Policies." *Review of Economic Dynamics* 11 (4): 721-744.

[14] Holz, Carsten (2009). “No Razor’s Edge: Reexamining Alwyn Young’s Evidence for Increasing Interprovincial Trade Barriers in China.” *Review of Economics and Statistics* 91 (3): 599-616.

[15] Hsieh, Chang-Tai and Peter Klenow (2009). “Misallocation and Manufacturing TFP in China and India.” *Quaterly Journal of Economics* 124 (4): 1403-48.

[16] Poncet, Sandra (2003). “Measuring Chinese Domestic and International Integration.” *China Economic Review* 14 (1): 1-21.

[17] Restuccia, Diego and Richard Rogerson (2008). “Policy Distortions and Aggregate Productivity with Heterogeneous Plants.” *Review of Economic Dynamics* 11 (4): 707-720.

[18] Restuccia, Diego, Dennis Yang, and Xiaodong Zhu (2008). “Agriculture and aggregate productivity: A quantitative cross-country analysis.” *Journal of Monetary Economics* 55 (2): 234-250.

[19] Ruhl, Kim J. (2008) “The International Elasticity Puzzle.” mimeo.

[20] Vollrath, Dietrich (2009). “How important are dual economy effects for aggregate productivity?” *Journal of Development Economics* 88 (2): 325-334.

[21] Young, Alwyn (2000). “The Razor’s Edge: Distortions and Incremental Reform in the People’s Republic of China.” *Quaterly Journal of Economics* 115 (4): 1091-1135.

[22] Zhang, Xiaobo and Kong-Yam Tan (2007). “Incremental Reform and Distortions in China’s Product and Factor Markets.” *World Bank Economic Review* 21 (2): 279-299.

Table 1: TFP Growth Rates, Efficient and Actual

Period	1985-2007	1985-1997	1997-2007
Efficient	6.16%	5.96%	6.41%
Actual	6.06%	6.38%	5.68%
Impact of Distortion :			
Actual-Efficient	-0.10%	0.42%	-0.73%

Table 2: Robustness: Impact of Distortions

	Average Distortion	TFP Growth Differential: Actual-Efficient		
Period	1985-2007	1985-2007	1985-1997	1997-2007
Baseline	0.28	-0.10%	0.42%	-0.73%
$\sigma^{-1} = 3$	0.39	-0.01%	0.56%	-0.69%
$\phi^{-1} = 3$	0.29	-0.03%	0.56%	-0.73%
$a = 0.5$	0.30	-0.04%	0.78%	-1.02%

Table 3: Average TFP Growth Rates by Region

Period	1997-2007			
	East	Middle	Northeast	West
Actual	5.70%	6.24%	6.67%	4.37%
No Within-Province Distortion	6.21%	6.82%	7.21%	5.24%
Impact of Distortion:				
Change on TFP growth	-0.51%	-0.58%	-0.54%	-0.87%

Figure 1:

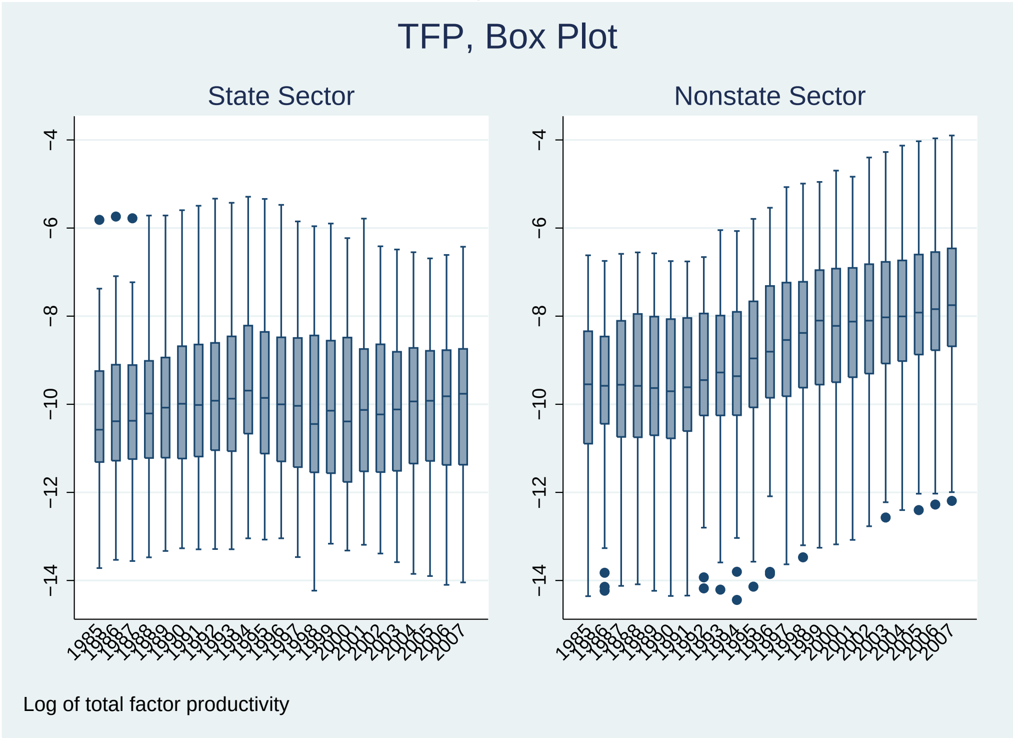


Figure 2:

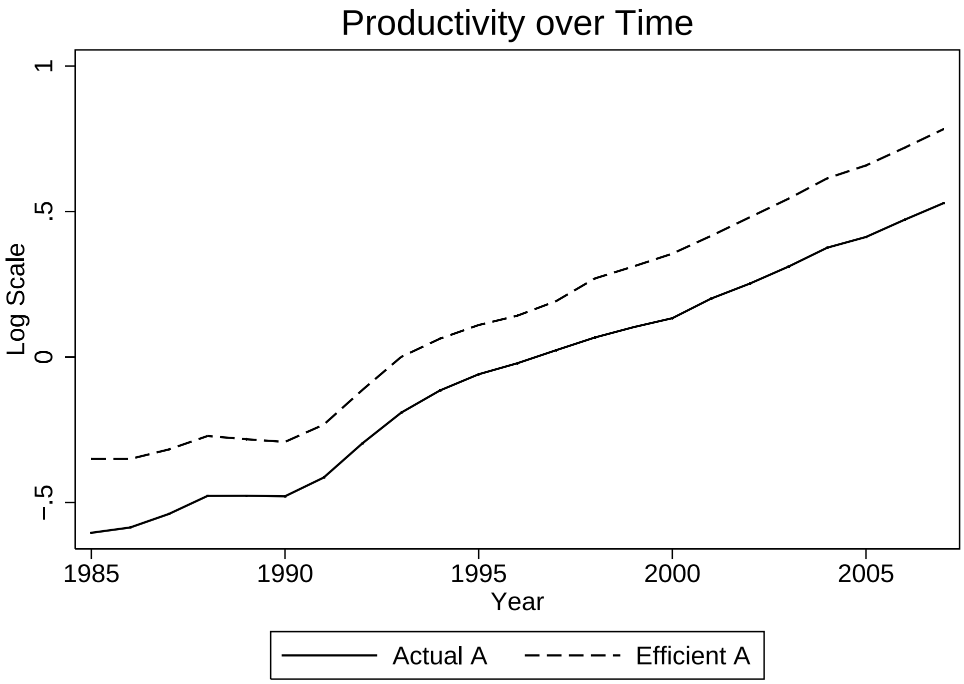


Figure 3:

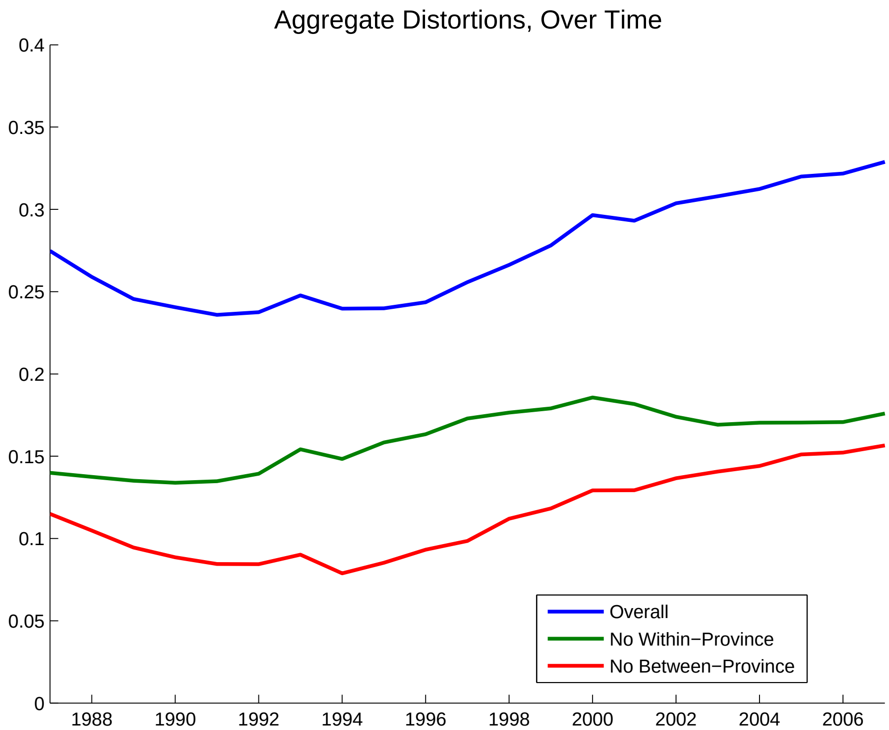

Aggregate Distortions, Over Time
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Overall
No Within−Province
No Between−Province

Figure 4:

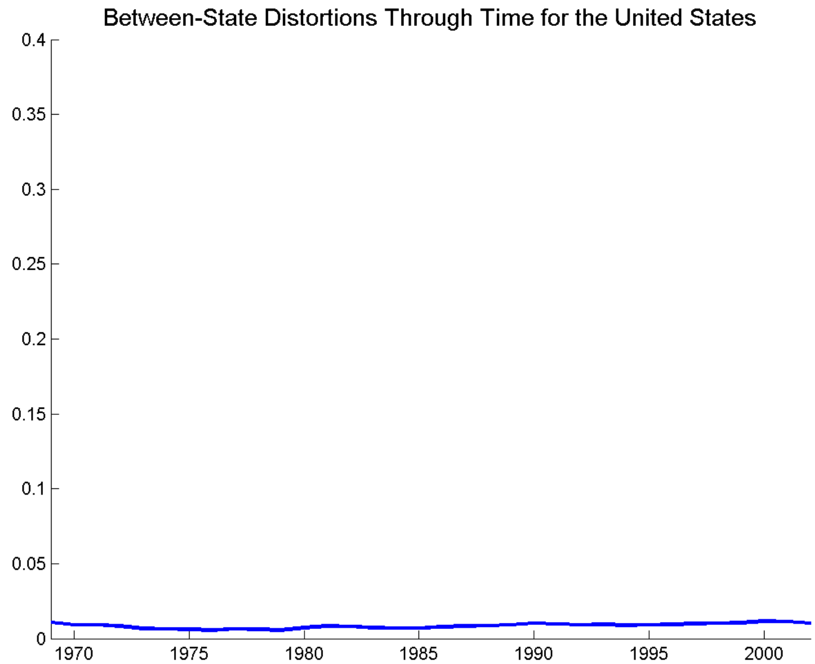


Figure 5:

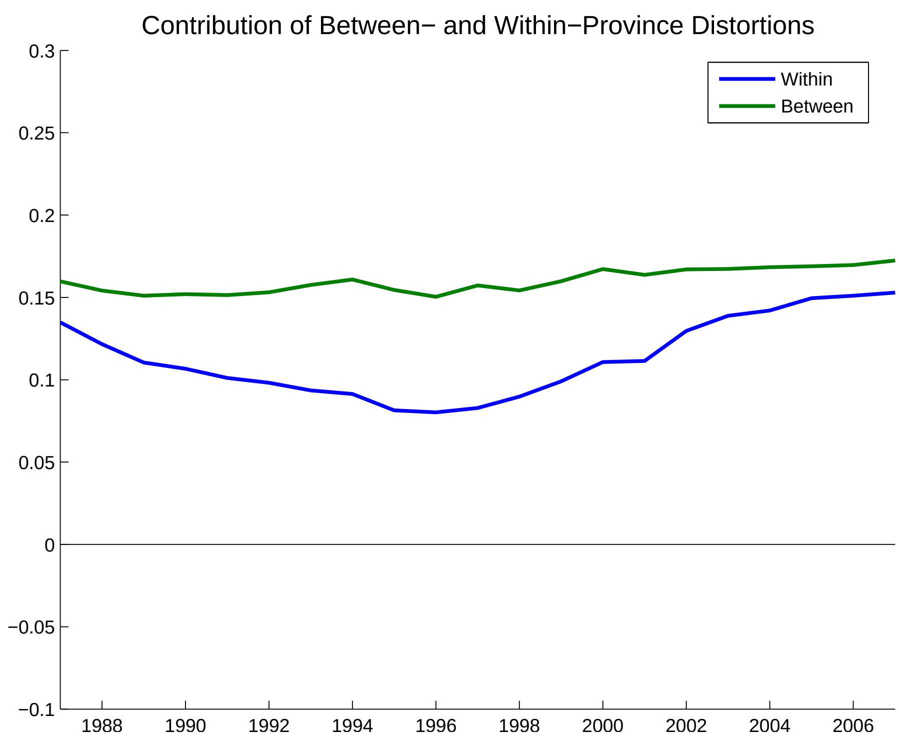


Figure 6:

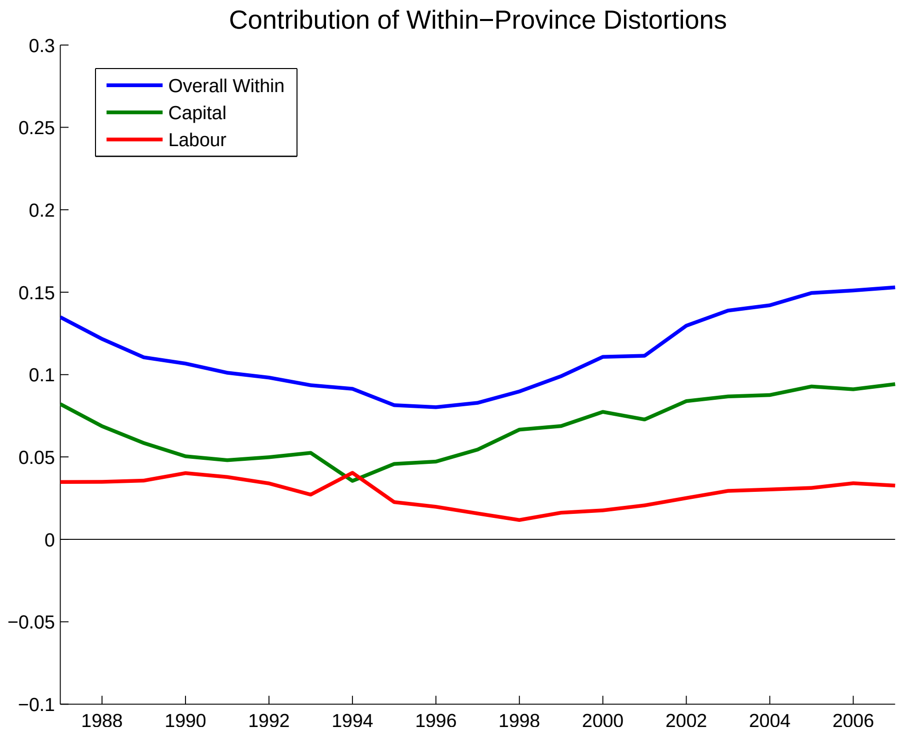


Figure 7:

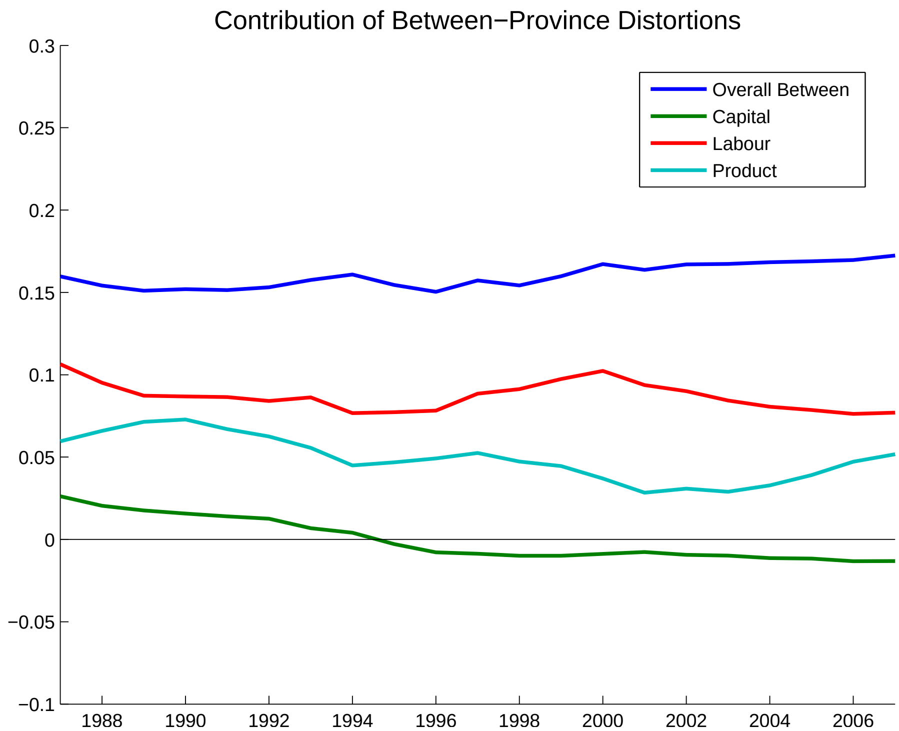


Figure 8:

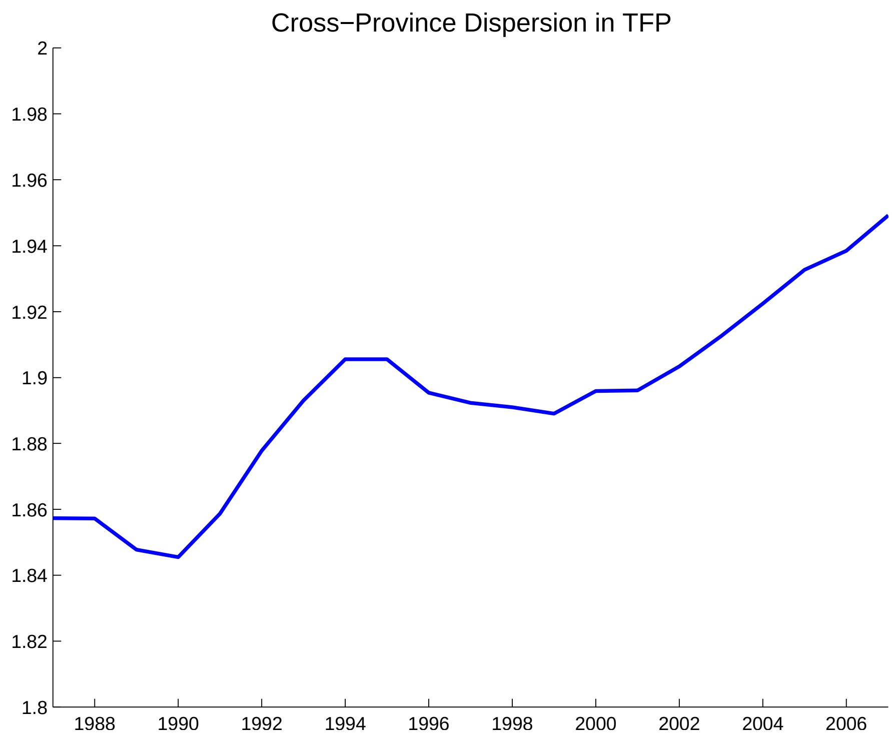


Figure 9:

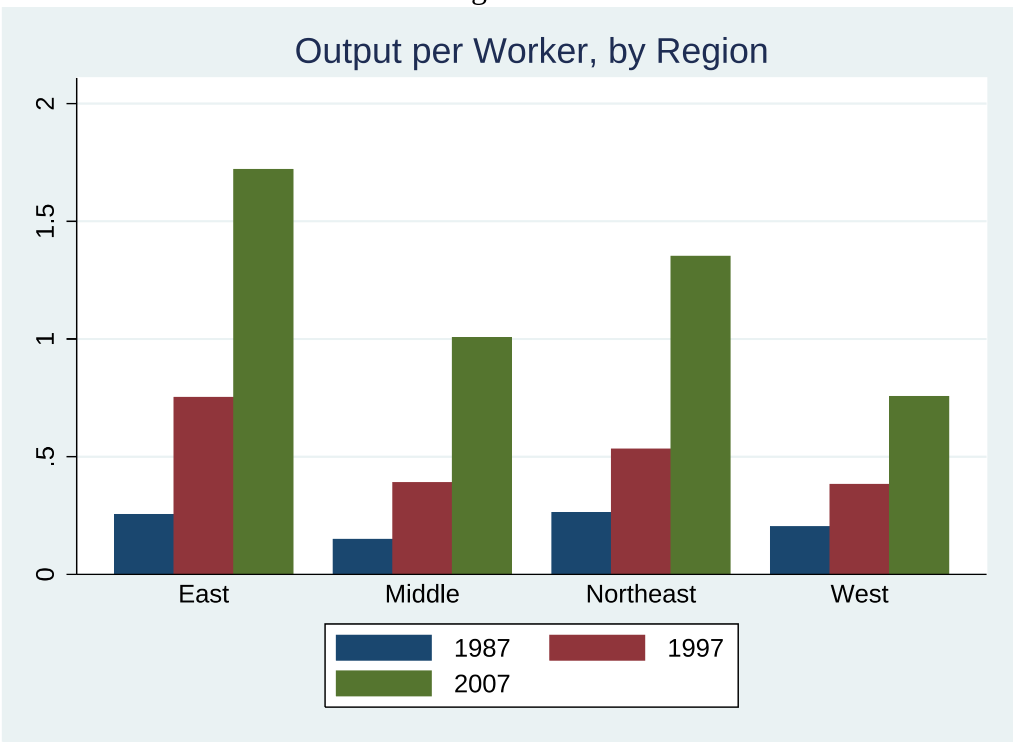


Figure 10:

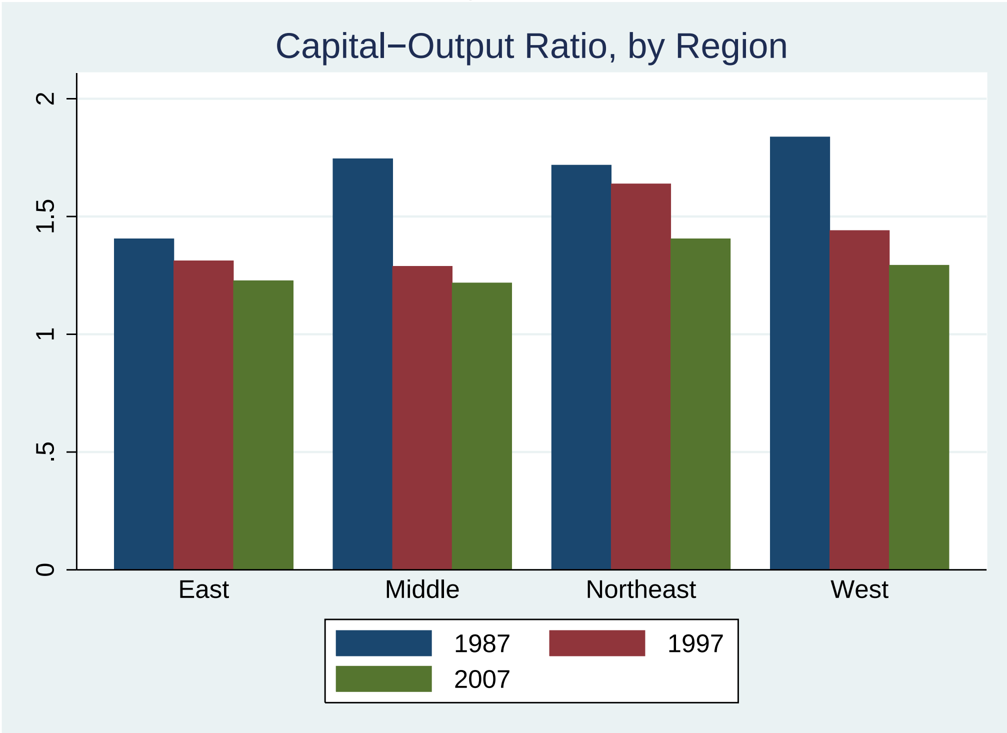


Figure 11:

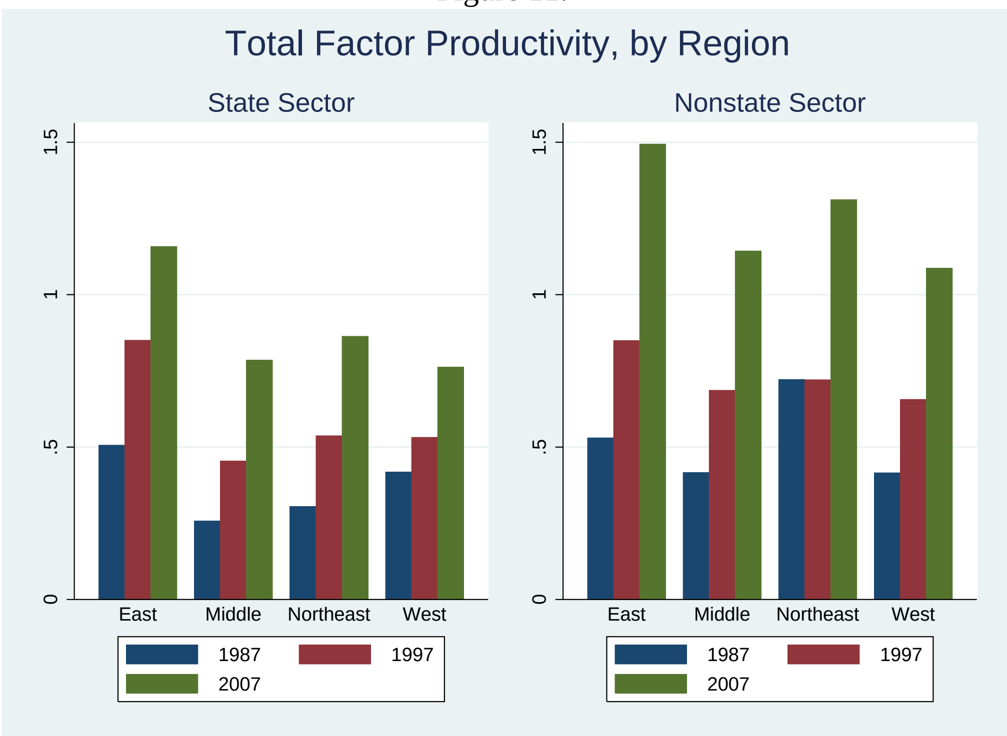
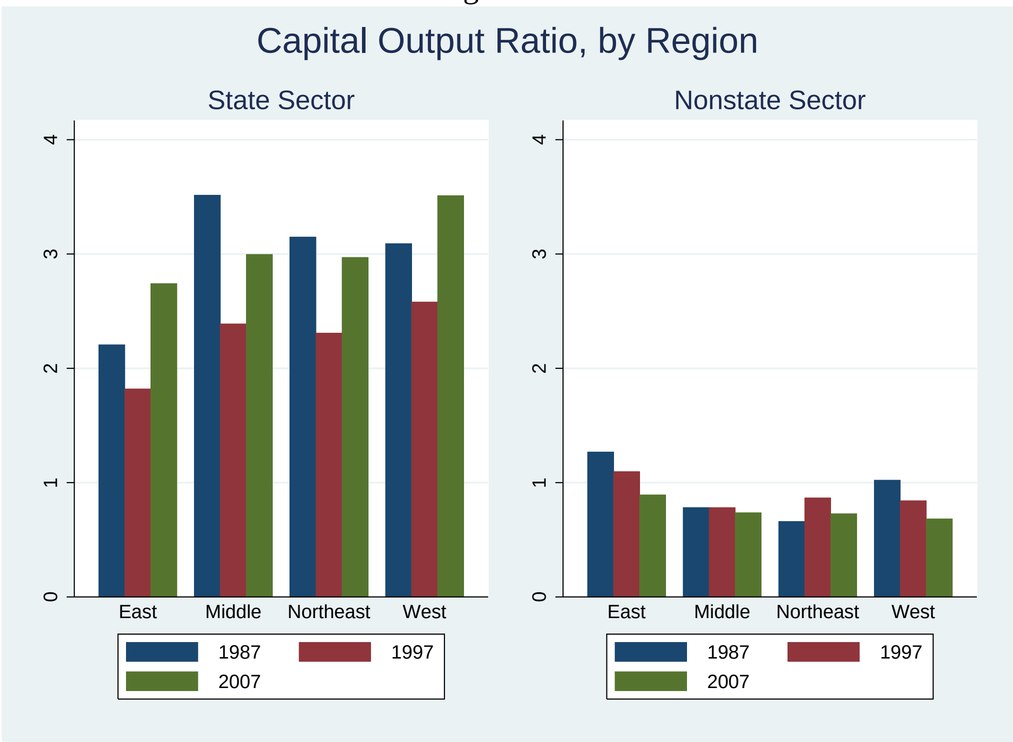
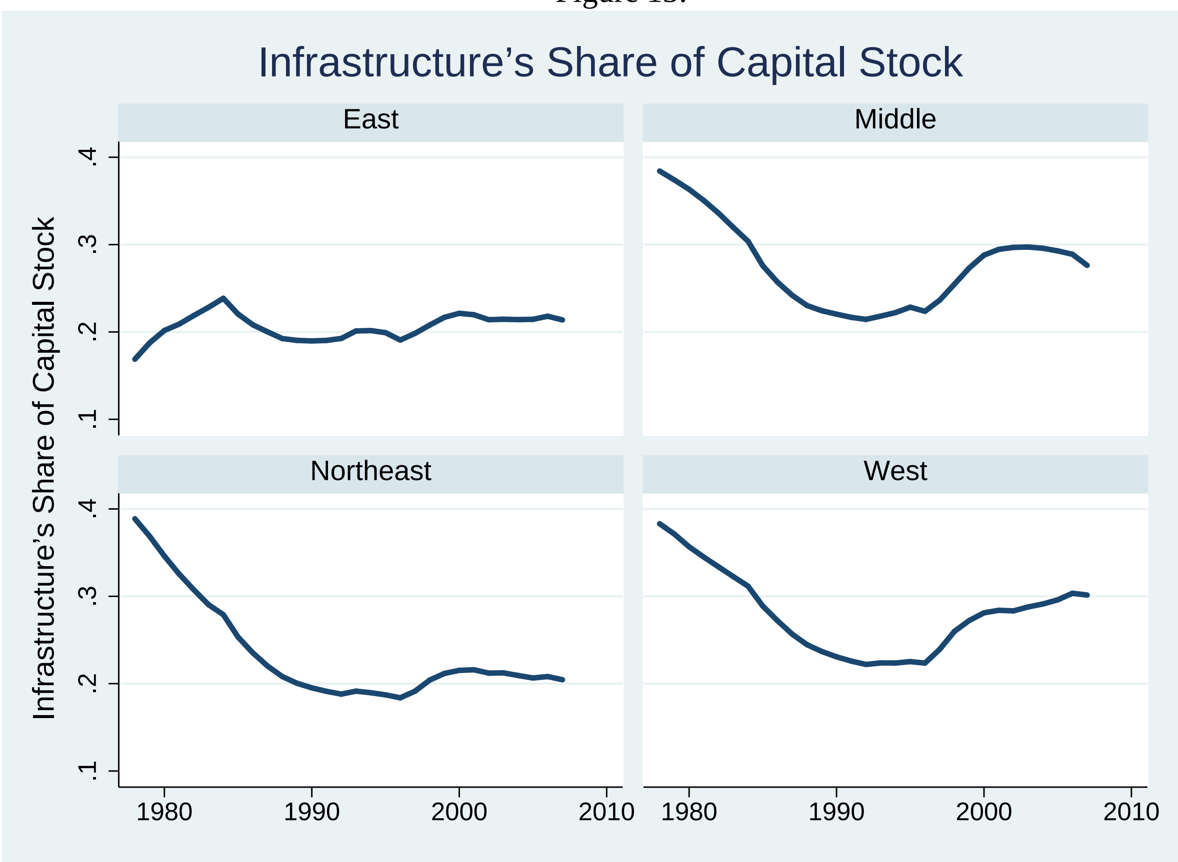


Figure 12:



Capital Output Ratio, by Region
State Sector
Nonstate Sector
0
1
2
3
4
East
Middle
Northeast
West
1987
1997
2007

Figure 13:



Infrastructure's Share of Capital Stock
East
Middle
Northeast
West
Infrastructure's Share of Capital Stock
.1
.2
.3
.4
1980
1990
2000
2010

Figure 14:

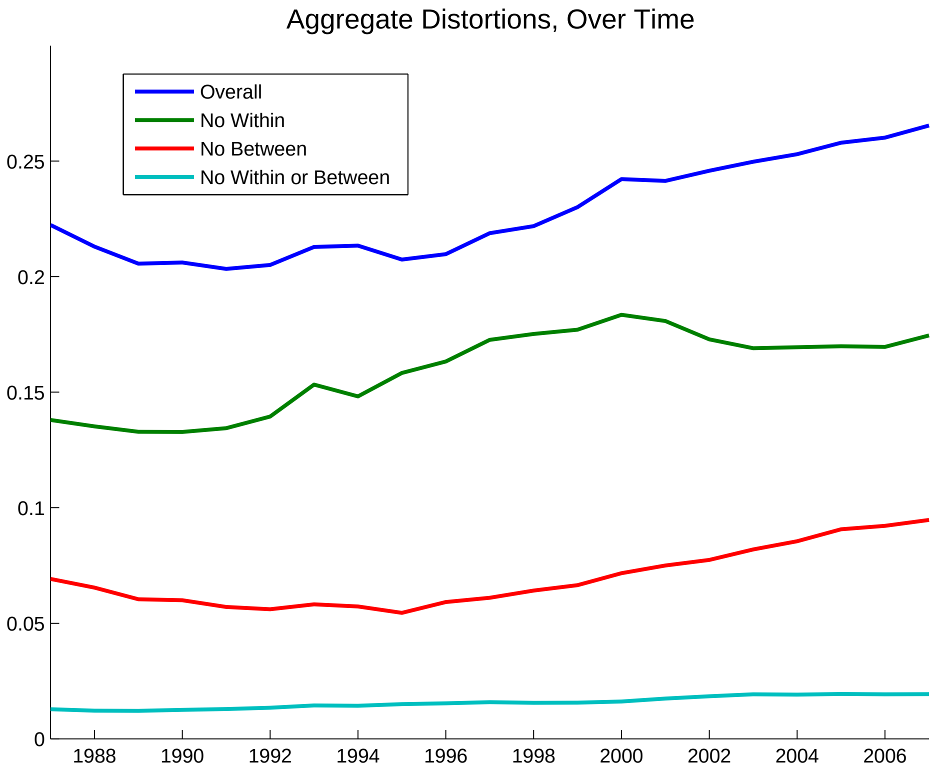

Aggregate Distortions, Over Time
Overall
No Within
No Between
No Within or Between
0.25
0.2
0.15
0.1
0.05
0
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

Figure 15:

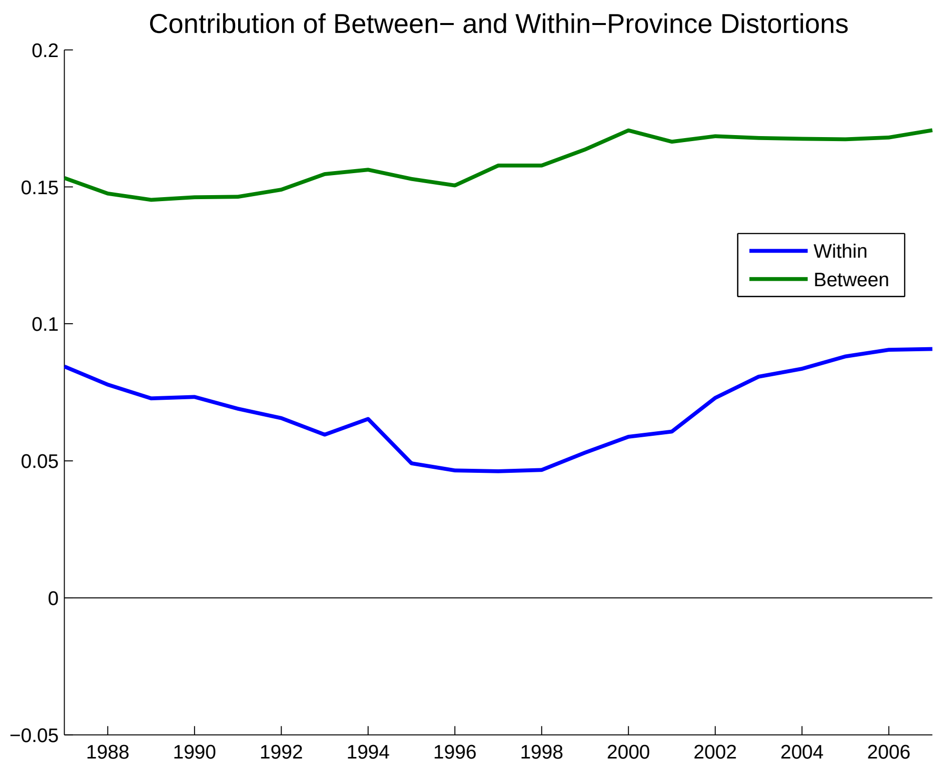

Contribution of Between− and Within−Province Distortions
0.2
0.15
0.1
0.05
0
−0.05
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Within
Between

Figure 16:

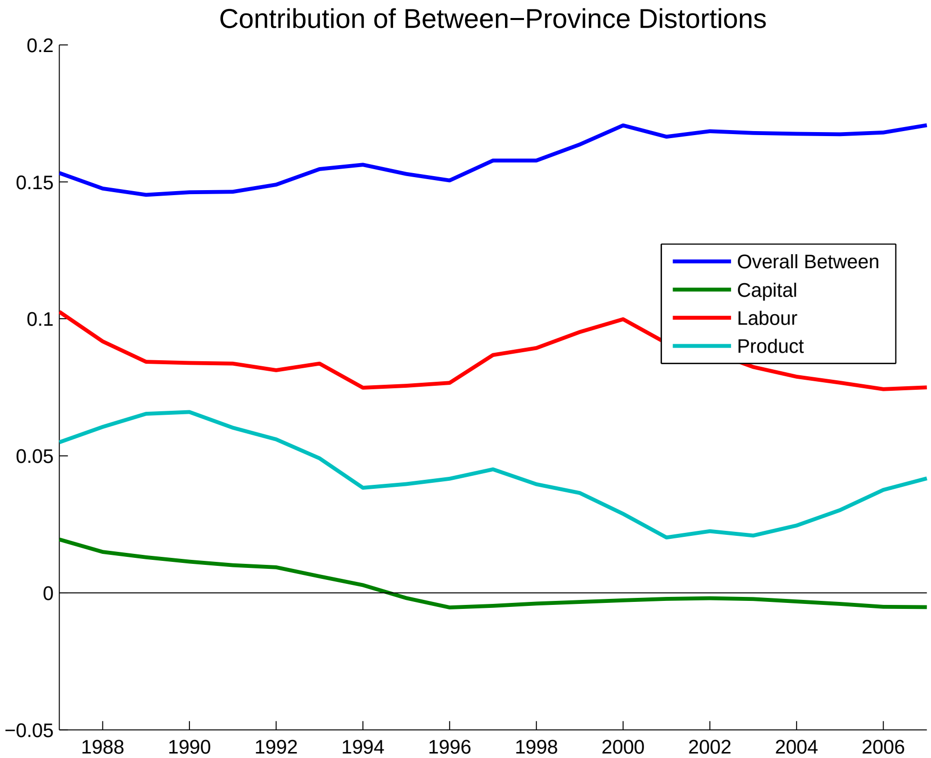
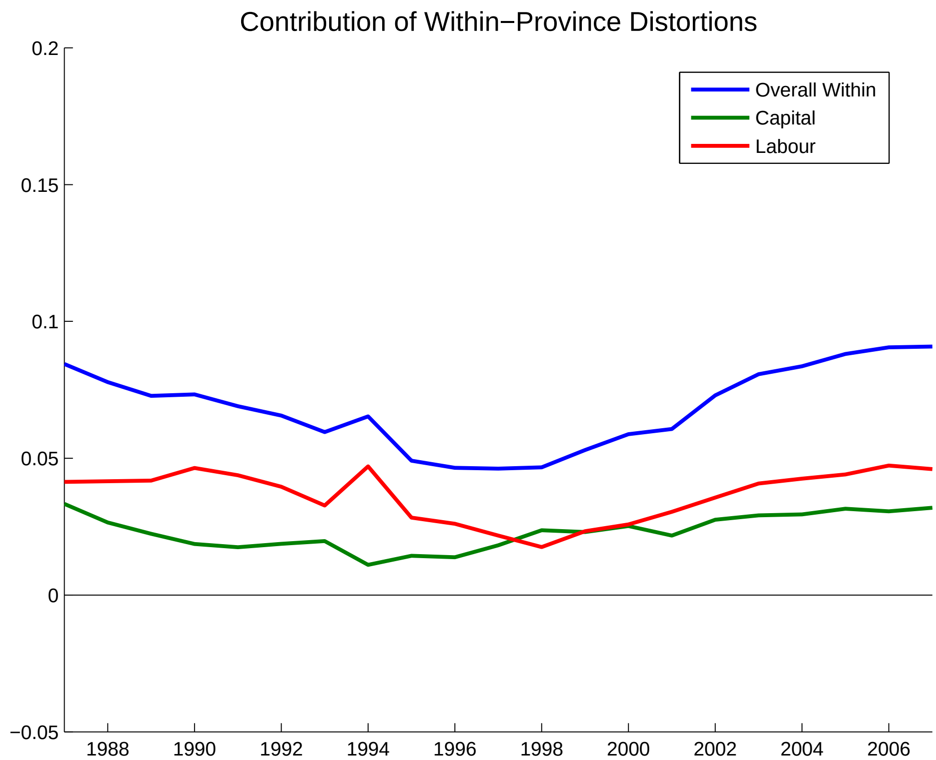

Contribution of Between−Province Distortions
0.2
0.15
0.1
0.05
0
−0.05
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
Overall Between
Capital
Labour
Product

Figure 17:


Contribution of Within−Province Distortions
Overall Within
Capital
Labour
0.2
0.15
0.1
0.05
0
−0.05
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006

Not for Publication Appendix

Proof of Propositions

Since the optimal allocation in Proposition 1 is just a special case of the competitive equilibrium when all taxes are set to one. We just prove Proposition 2 here.

For any set of taxes $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\ldots,m; j=n,s}$, we now show that there is a unique allocation that solves firm's profit maximization problems. Remember the stand-in firm's profit maximization problem in province i and sector j is

$$\max_{K_{ij},L_{ij}} \left\{ P_{ij}A_{ij}L_{ij}^{a}K_{ij}^{1-a} - \tau_{ij}^l wL_{ij} - \tau_{ij}^k rK_{ij} \right\}$$

which implies the following standard first-order conditions:

$$aP_{ij}A_{ij}L_{ij}^{a-1}K_{ij}^{1-a} = \tau_{ij}^l w \quad (15)$$

$$bP_{ij}A_{ij}L_{ij}^{a}K_{ij}^{-a} = \tau_{ij}^k r \quad (16)$$

Taking the ratio of the two equations yields the following:

$$\frac{K_{ij}}{L_{ij}} = \left(\frac{\tau_{ij}^l w}{a}\right)\left(\frac{\tau_{ij}^k r}{1-a}\right)^{-1} \quad (17)$$

Substituting it into (15), we have

$$aP_{ij}A_{ij}\left[\frac{\tau_{ij}^l w}{a}\frac{1-a}{\tau_{ij}^k r}\right]^{1-a} = \tau_{ij}^l w.$$

Solving for P_{ij},

$$P_{ij} = A_{ij}^{-1}\left(\frac{\tau_{ij}^l w}{a}\right)^{a}\left(\frac{\tau_{ij}^k r}{1-a}\right)^{1-a} = p_{ij}\lambda_p \quad (18)$$

Here

$$p_{ij} = A_{ij}^{-1}\tau_{ij}^{la}\tau_{ij}^{k1-a}$$

and

$$\lambda_p = \left(\frac{w}{a}\right)^{a}\left(\frac{r}{1-a}\right)^{1-a}$$

Note that

$$Y_{ij} = A_{ij} L_{ij}^{a} K_{ij}^{1-a} = A_{ij} \left(\frac{K_{ij}}{L_{ij}}\right)^{1-a} L_{ij}$$

Thus, from (17), we have

$$Y_{ij} = A_{ij} \left(\frac{\tau_{ij}^{l} w}{a}\right)^{1-a} \left(\frac{\tau_{ij}^{k} r}{1-a}\right)^{a-1} L_{ij} = U_{ij} L_{ij} \tag{19}$$

Here

$$U_{ij} = A_{ij} \left(\frac{\tau_{ij}^{l} w}{a}\right)^{1-a} \left(\frac{\tau_{ij}^{k} r}{1-a}\right)^{a-1} = u_{ij} \lambda_{u} \tag{20}$$

is the average product of labor in province i and sector j,

$$u_{ij} = A_{ij} \tau_{ij}^{l 1-a} \tau_{ij}^{ka}$$

and

$$\lambda_{u} = \left(\frac{w}{a}\right)^{1-a} \left(\frac{r}{1-a}\right)^{a-1}$$

Substituting (19) into (2), we have

$$Y_{i} = \left[(U_{is} L_{is})^{1-\phi} + (U_{in} L_{in})^{1-\phi}\right]^{\frac{1}{1-\phi}} = \left[\left(u_{is} l_{s|i}\right)^{1-\phi} + \left(u_{in} l_{n|i}\right)^{1-\phi}\right]^{\frac{1}{1-\phi}} \lambda_{u} L_{i} = u_{i} \lambda_{u} L_{i} \tag{21}$$

Here

$$u_{i} = \left[\left(u_{is} l_{s|i}\right)^{1-\phi} + \left(u_{in} l_{n|i}\right)^{1-\phi}\right]^{\frac{1}{1-\phi}} \tag{22}$$

From (7), (19) and (21), then, we have

$$\frac{P_{ij}}{P_{i}} = \frac{p_{ij}}{p_{i}} = \left(\frac{u_{ij} L_{ij}}{u_{i} L_{i}}\right)^{-\phi} = \left(\frac{u_{ij} l_{j|i}}{u_{i}}\right)^{-\phi}$$

Here

$$p_{i} = \left(p_{is}^{\frac{\phi}{\phi-1}} + p_{in}^{\frac{\phi}{\phi-1}}\right)^{\frac{\phi-1}{\phi}} \tag{23}$$

Sovling for $l_{j|i}$

$$l_{j|i} = \frac{u_{i}}{u_{ij}} \left(\frac{p_{ij}}{p_{i}}\right)^{-\frac{1}{\phi}}.$$

By definition,

$$1 = l_{s|i} + l_{n|i} = u_i p_i^{\frac{1}{\phi}} \left(u_{is}^{-1} p_{is}^{-\frac{1}{\phi}} + u_{in}^{-1} p_{in}^{-\frac{1}{\phi}} \right)$$

which implies that

$$u_i = \frac{p_i^{-\frac{1}{\phi}}}{u_{is}^{-1} p_{is}^{-\frac{1}{\phi}} + u_{in}^{-1} p_{in}^{-\frac{1}{\phi}}} \tag{24}$$

and

$$l_{j|i} = \frac{u_{ij}^{-1} p_{ij}^{-\frac{1}{\phi}}}{u_{is}^{-1} p_{is}^{-\frac{1}{\phi}} + u_{in}^{-1} p_{in}^{-\frac{1}{\phi}}} \tag{25}$$

From equation (6), we have

$$\frac{\widehat{P_i}}{P} = \frac{\widehat{p_i}}{p} = \left(\frac{Yi}{Y} \right)^{-\sigma} = \left(\frac{U_i L_i}{\left[\sum_{i=1}^{m} (U_i L_i)^{1-\sigma} \right]^{1-\sigma}} \right)^{-\sigma} = \left(\frac{u_i L_i}{\left[\sum_{i=1}^{m} (u_i l_i)^{1-\sigma} \right]^{1-\sigma} L} \right)^{-\sigma}$$

Let

$$u = \left[\sum_{i=1}^{m} (u_i l_i)^{1-\sigma} \right].^{1-\sigma} \tag{26}$$

Then, we have

$$\frac{\widehat{p_i}}{p} = \left(\frac{u_i}{u} l_i \right)^{-\sigma}$$

or

$$l_i = u_i^{-1} u p^{\frac{1}{\sigma}} \widehat{p_i}^{-\frac{1}{\sigma}}$$

By definition,

$$1 = \sum_{i=1}^{m} l_i = \sum_{i=1}^{m} u_i^{-1} u p^{\frac{1}{\sigma}} \widehat{p_i}^{-\frac{1}{\sigma}} = u p^{\frac{1}{\sigma}} \sum_{i=1}^{m} u_i^{-1} \widehat{p_i}^{-\frac{1}{\sigma}}$$

which implies that

$$u = \left(\sum_{i=1}^{m} u_i^{-1} \widehat{p_i}^{-\frac{1}{\sigma}} \right)^{-1} p^{-\frac{1}{\sigma}}$$

and

$$l_i = \frac{u_i^{-1} \widehat{p_i}^{-\frac{1}{\sigma}}}{\sum_{i'=1}^{m} u_{i'}^{-1} \widehat{p_{i'}}^{-\frac{1}{\sigma}}} \tag{27}$$

Equation (25) and (27) provide the expression for the equilibrium labour allocation for the given set of taxes. The equlibrium capital allocation $k_{j|i}$ and k_i can be solved in a similar way. From these expressions it is clear that mutliplying taxes in all provinces and sectors by a positive constant will not change the resulting equilibrium allocation of labour and capital.

Next, we show for any allocation how we can identify the set of taxes that implement the allocation in a competitive equilbrium. First, note that

$$L_{ij} \propto l_{j|i} l_i \qquad K_{ij} \propto k_{j|i} k_i$$

So,

$$Y_{ij} \propto \widetilde{Y}_{ij} \equiv A_{ij} \left(l_{j|i} l_i \right)^a \left(k_{j|i} k_i \right)^{1-a}$$

and

$$Y_i \propto \widetilde{Y}_i \equiv \left(\widetilde{Y}_{in}^{1-\phi} + \widetilde{Y}_{is}^{1-\phi} \right)^{\frac{1}{1-\phi}}$$

From (6) and (7), then, we have

$$P_{ij} = P_i Y_{ij}^{-\phi} Y_i^{\phi} = \tau_i^{y-1} Y_{ij}^{-\phi} Y_i^{\phi-\sigma} P Y^{\sigma}.$$

Thus,

$$P_{ij} \propto \tau_i^{y-1} \widetilde{Y}_{ij}^{-\phi} \widetilde{Y}_i^{\phi-\sigma}$$

From (11) and (12), we have

$$\tau_{ij}^{l} \propto \frac{\tau_i^{y-1} \widetilde{Y}_{ij}^{-\phi} \widetilde{Y}_i^{\phi-\sigma}}{l_{j|i} l_i} \quad \text{and} \quad \tau_{ij}^{k} \propto \frac{\tau_i^{y-1} \widetilde{Y}_{ij}^{-\phi} \widetilde{Y}_i^{\phi-\sigma}}{k_{j|i} k_i}.$$

So, if we can identify τ_i^y, labour and capital taxes can be identified as above. Finally, to identify the former, we can substitute the expression for labour and capital taxes above into equation (27), which can be used to solve for the unique value of τ_i^y up to a proportional constant.

Construction of Infrastructure Capital Stock

This outlines the procedures used to adjust the state-sector capital stock data. The period 1981-2007 is analyzed, using data from the Statistical Yearbook of China and Fixed Asset Investment Yearbooks for various years. Different investment categories are listed by the statistical yearbooks for different time periods. The various categories from each source, with bold categories representing a close approximation to infrastructure, are as follows:

- 1981-1984, Statistical Yearbook of China (State-Sector Capital Construction Only)
  - Industry; Construction; and resources prospecting (with subcategory for ***resource prospecting***); Agriculture, forestry, water conservancy and meteorology (with subcategory for ***water conservancy***); ***Transport, posts and telecommunications*** (with subcategory for railways); Commerce, catering, and service trades and materials supply and marketing; banking and insurance; scientific researches culture, education, public health and social welfare; ***civil public utilities***; ***government agencies, public organizatons, and others***.
- 1985-1992, Statistical Yearbook of China (State-Sector Only)
  - Farming, forestry, animal husbandry, fishery, ***water conservancy***; Industry; ***Geological survey and prospecting***; Construction; ***Transportation, postal, telecommunication***; Commerce, food service, material supply, marketing, storage; Real estate, public services, residential and consultancy services; health care, sports, social welfare; education, culture, art, radio, TV; Scientific research, polytechnical serivce; banking, insurance; ***government agencies, parties, social organizations***; Other.
  - Subindustry: ***Power generation, steam and hot water production and supply*** (1985-1988).
- 1993-2002, Statistical Yearbook of China (94-02 All Sectors, 93 State)
  - Agr; Mining; Mfg; ***Elec, Gas and Water***; Construction; ***Geological prospecting and water conservancy***; ***Transportation, Storage, postal and telecommunication services***; wholesale and retail, catering; Banking and insurance; real estate; social services; health care, sports, and social welfare; education, culture, and arts, radio, film, TV; R&D, polytechnical services; ***government,parties, social organizations***; other.
- 2003-2006, Fixed Asset Investment Yearbook (All Sectors, 2006=Urban); 2007 Statistical Yearbook of China
  - Agr; Mining; Mfg; ***Elec, Gas and Water***; Construction; ***Transport***; Information tec; Wholesale and Retail Trade; Hotels and Catering; Financial Intermediation; Real Estate; Leasing; R&D; ***Water Mgmt, Env and Public Facilities***; Hshld Services; Edu-

cation; Health and Welfare; Culture and sports; ***Public mgmt and social org***; Int org; Other.

These infrastructure categories are associated with capital intensive activities that are mainly state activities.

There are some important details that one must consider in addition to the above. The previous table outlines many categories of fixed asset investment but certain years are missing important breakdowns. The following adjustments are made to the categorical data prior to beginning the analysis.

1. For 1985-1992 water does not exist as a separate category. Aggregate level data suggests that such investment is approximately 10% of overall agricultural investment in the 90s. However, 1981-1984 data, which does provide provincial-level data on the matter, points to a 50% rate. So, for the 1985-1992 period, water investment is assumed to equal 25% of total agricultural ("Farming, forestry, animal husbandry, fishery, water conservancy") investment.

2. Pre-1992 electricity and gas is also not provided for years except between 1985-1988 as a subcategory of industry fixed investment. Consistent with data from these four available years, we generate a power generation estimate equal to the 85-88 province-specific average share of industry investment to power generation. This ranges from 68% in Tibet, 34% in Fujian, to 9% in Beijing, Tianjin, and Shanghai. This share is then use to infer values for 81-84 and 89-92.

3. 1993-2002 transportation also appears to be far higher than surrounding years. This is likely due to the broader definition of transportation including all telecommunications investment during this period. The fraction of the transport category of the total investment is 10% in the post-2002 period while it often exceeds 20% between 1997 and 2002, and is approximately 14% between 1993 and 1997. We correct this additional investment by deflating the size of this category to be included as state-social investment to 2/3 of its original value (a figure that makes 2002 more consistent with 2003.

4. Only 2003-2007 and 1996 reports provincial breakdowns of fixed asset investment by category for all classes of investment, while other dates provide only capital construction, technical updates, real estate, and so on. Thus, the 2003-2007 and 1996 data provides a full breakdown by sector while the remaining years usually account for 2/3 of overall investment since 1985 and approximately 50% for the 1981-1984 period. We make no adjustment for

this, which implies we assume the state social investment share is identical across reporting categories. This is assumption is proved false in 1998, a year with all investment types available, with a 31% social share implied when using all data, but 40% when using the capital, real estate, and innovation categories. As a robustness check, we analyse the time series implied by adjusting pre-2003 shares downward by a factor of 1.2. All conclusions are robust.

The next issue to consider is the various investment types reported in the statistical and investment yearbooks, such as Capital Construction and Real Estate, for instance. Innovative Activities and Technical Updates likely reflect the same activity, but merely represent a series-name change. For years in which the total fixed investment by sector and province are not available, we estimate that total using a sum of the capital, innovative, real estate, and technical investment types for that year. For 1998 we ignore the "All" type and do calculations consistent to the entire 1997-2002 set. Thus, 1996 and 2003-2007 have the "All" type used exclusively. Table 4 provides the number of provinces, cross tabulated by year and type, for which data is available.

A final adjustment is crude, but recognizes that some portion of the social investment categories is nonstate. From the 2007 data, approximately 75% of the highlighted sectors (varying from 65% for culture to 81% for transport) are in the state sector. Given that sectors change through time, and no provincial data is available for the ownership/sector breakdown, we apply a uniform deflation of the social investment data by 0.75 prior to determining its share of overall investment. Next, given that 1994-onwards includes all ownership types within the total, we adjust the social investment share by the inverse of the observed state share of fixed investment, by province, from the China Data Online dataset (Statistical Yearbook sources).

Thus, our measure of state infrastructure investment expenditures is given by the following:

$$StateInfraInvest_{it} = 0.75 \left(\frac{TotalInfraInvest_{it}}{StateInvest_{it}} \right)$$

Table 4: Provincial Data Availability, by Investment Type and Year

Year	All	Capital Construction	Innovative Activities	Real Estate	Technical Updates
1981	0	29	0	0	0
1982	0	29	0	0	0
1983	0	29	0	0	0
1984	0	29	0	0	0
1985	0	29	0	0	29
1986	0	29	0	0	29
1987	0	29	0	0	29
1988	0	30	0	0	30
1989	0	30	0	0	30
1990	0	30	0	0	30
1991	0	30	0	0	30
1992	0	30	0	0	30
1993	0	30	0	0	30
1994	0	30	0	30	30
1995	0	30	0	30	30
1996	30	0	0	0	0
1997	0	31	31	31	0
1998	31	31	31	31	0
1999	0	31	31	31	0
2000	0	31	31	31	0
2001	0	31	31	31	0
2002	0	31	31	31	0
2003	31	0	0	0	0
2004	31	0	0	0	0
2005	31	0	0	0	0
2006	31 (urban)	0	0	0	0
2007	31	0	0	0	0