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Factor market distortions across time, space and sectors in China [☆]

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ABSTRACT

In this paper, we measure TFP losses in China's non-agricultural economy associated with labour and capital misallocation across provinces and sectors between 1985 and 2007. We also decompose the overall loss into factor market distortions within provinces (between state and non-state sectors) and distortions between provinces (within sectors). Over the entire period, misallocation lowers aggregate non-agricultural TFP by an average of twenty percent. However, after initially declining, these losses increased appreciably beginning in the mid-1990s. This reversal can be attributed almost exclusively to increasing misallocation of capital between state and non-state sectors within provinces, while losses from between province misallocation remained fairly constant. We argue that the recent increase in capital market distortions is related to government policies that encourage investments in the state sector at the expense of investments in the more productive non-state sector.

1. Introduction

Some of the rapid growth that China has enjoyed the last three and a half decades has likely come from reductions in distortions as a result of economic reform. An important feature of China's pre-reform economy was a high degree of local autarky. At the provincial level, self-sufficiency in both agriculture and industry were aggressively pursued, and reinforced through limited investment in transportation infrastructure (Donnithorne, 1972). These policies were coupled with tight restrictions on labour mobility both within and between provinces through the household registration or hukou system and strict control over the allocation of capital through the use of administrative credit plans. With the onset of economic reform in the late 1970s, some of the restraints on resource mobility persisted. In addition to restrictions on the mobility of labour out of the countryside (Chan et al., 2008), local protectionism and trade barriers arose to impede the inter-regional flow of goods (Young, 2000; Poncet, 2003). A credit plan continued to be used to ensure access to new loans by state-owned firms (Brandt and Zhu, 2000), the effects of which were reinforced by barriers to the flow of capital across regions (Boyreau-Debray and Wei, 2005; Dollar and Wei, 2007).

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The general presumption is that many of these barriers have now been significantly relaxed. For example, the stock of non-hukou migrants is currently in upwards of 150 million, half of which have crossed a provincial boundary. In addition, annual hukou migration averages 20 million per year. There have also been significant increases in inter-regional trade accompanying a reduction in barriers (Holz, 2009; Holz, in press). Reform in the banking system dating from the late 1990s, including the development of an inter-bank market, may be allowing a more efficient regional allocation of capital through the inter-bank market and other channels.

Possibly offsetting these tendencies is the fact that the state continues to exercise considerable influence on the allocation of factors of production – land, labour and capital (World Bank, 2012) that is reflected in differences in productivity across regions and forms of ownership. A majority of investment resources continues to be directed by China's highly regulated financial system to state-owned firms and activities in which the local governments are often a beneficiary (Walter and Howie, 2011). Since the late 1990s, there have also been efforts through such policies as Xibu Kaifa (Develop the Great West) to redress perceived policy biases in favour of coastal provinces by reallocating investment resources towards the interior regions. Persistent differences in returns to capital and labour between the state and the non-state sectors have recently been documented by Brandt and Zhu (2010) and Kamal and Lovely (2012).

Given these opposing developments, it is important to measure the overall impact of factor market distortions in China and examine their evolution over time. In a recent paper, Hsieh and Klenow (2009) investigate the impact of factor misallocation across firms within four-digit manufacturing industries on aggregate total factor productivity (TFP) in China and India, using an approach proposed by Restuccia and Rogerson (2008). They found that a more efficient factor allocation contributed to around 2 percent a year aggregate TFP growth in China's manufacturing sector between 1998 and 2005.

In this paper, we follow this approach, but examine factor misallocation and its impact on TFP at a more aggregate level, between provinces and between the state and the non-state sectors in China's non-agricultural economy, which includes both manufacturing and services. We focus on factor misallocation at this level of aggregation because, as we discussed above, there are significant barriers to factor mobility across regions and forms of ownership in China. Our analysis also covers a longer period, from 1985 to 2007, so that we can examine the evolution of factor misallocation over time. Finally, we decompose the overall TFP loss into the losses due to *between-province* and *within-province inter-sectoral* distortions.

Our main results are the following:

- On average, the misallocation of factors across provinces and sectors resulted in a reduction of non-agricultural TFP of at least 20%, with the within-province distortions accounting for more than half of the total loss.
- TFP losses from between-province distortions were relatively constant over the entire period.
- Despite significant inter-provincial labour flows, the TFP loss from between-province labour market distortions remains high due to an increase in the cross-province dispersion in TFP.
- The measure of within-province distortions declined sharply between 1985 and 1997, contributing to 0.52% non-agricultural TFP growth per year, but then increased significantly in the last ten years, reducing the non-agricultural TFP growth rate by 0.5% a year.
- Almost all of the within-province distortions was due to the misallocation of capital between the state and the non-state sectors, which increased sharply in recent years.

The magnitude of average TFP loss due to factor misallocation that we estimate (20%) for the non-agricultural economy is slightly lower than the estimate of Hsieh and Klenow (30%) for the manufacturing sector. A more important difference between our estimate and Hsieh and Klenow's is the trend after 1997. They found that the impact of distortions declined for the manufacturing sector, while we find the impact of distortions increased for the non-agricultural sector as a whole. Hsieh and Klenow only measure the impact of *within-industry* misallocation for the manufacturing sector alone, suggesting two potential reasons for the difference in results: (1) increased *between-industry* distortions for the manufacturing sector; and (2) increased distortions within the service sector and between the manufacturing and service sectors. We do not have data that would allow us to separate services from manufacturing activities. Also note that Hsieh and Klenow study micro-distortions between individual producers while we focus on sectoral and geographic aggregates.

Our result of the increasing impact of factor market distortions (especially the misallocation of capital between the state and the non-state sector) since 1997 is robust to alternative specifications of the model and alternative parameter values that we use to measure the distortions. It provides quantitative evidence for the view that China's capital markets have become more distorted in recent years. Given the rapid growth of the Chinese economy since 1997, this result may come as a surprise. However, the problem has been widely recognized within China, with ongoing debate over Guojin Mintui (the state advances, the private sector retreats), and discussed outside by political scientists and financial practitioners (see, for example, Huang, 2008, and Walter and Howie, 2011).

This paper is part of a recent literature that investigates the impact of misallocation of factors, either across sectors or across firms within sectors or industries, on aggregate productivity. Among many others, Gollin et al. (2004), Restuccia et al. (2008), Vollrath (2009) and Song et al. (2011) analyze the sectoral dimension while Alfaro et al. (2008), Banerjee and Duflo (2008), Guner et al. (2008), Restuccia and Rogerson (2008), Bartelsman et al. (2009) and Hsieh and Klenow (2009) focus on the misallocation across firms within a sector. Adamopoulos and Restuccia (2011) examine the impact of misallocation across production units within agriculture on misallocation between the agricultural and non-agricultural sector. Like us, Song et al. (2011) also emphasize the wedges in the returns to capital between the state and the non-state sectors. However, they do not consider factor allocation across provinces nor quantify the TFP loss associated with distortions, which is the focus of our paper.

Several existing studies have used separate measures of dispersion in the individual returns to labour and capital to study China's factor market distortions. Boyreau-Debray and Wei (2004), Dollar and Wei (2007), and Bai et al. (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 measures are informative about factor market distortions, there is no clear link between them and aggregate TFP.

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 and human capital in Section 6 and Section 7 concludes.

2. A framework for measuring factor market distortions

In this paper, we consider a static allocation problem. For each year, we take total employment and total capital stock as given and examine the allocation of the two factors across provinces and between the state and non-state sectors. Consider an economy with m provinces, indexed by $i = 1, \ldots, m$, and two sectors, state and non-state, indexed by $j = s, n$, respectively. We assume Cobb–Douglas production technologies with the same factor elasticities in all provinces and sectors[1]:

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

Here Y_{ij}, L_{ij}, K_{ij} and A_{ij} are the real GDP, employment, capital stock and TFP in province i and sector j. It is important to note that Y_{ij} is the real GDP and A_{ij} is the quantity TFP. To measure them we need provincial and sectoral deflators in addition to measures of nominal GDP, employment and capital stock. While we have estimates of provincial deflators, no data on sectoral deflators are available. To deal with this problem, we follow Hsieh and Klenow (2009)'s approach and infer the sectoral price information from nominal value-added shares by using a product market equilibrium condition that we will discuss in Section 2.3 below. The exact procedure will be discussed in Section 4.2.

We 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:

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

and

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

Here ϕ^{-1} and σ^{-1} are the elasticities of substitution among sectors and provinces, respectively, and ω_i is province i's weight in aggregate GDP. Note that the state and non-state sectors' output appear symmetrically in the provincial GDP function without weights. We make this assumption mainly because both the state and non-state firms are present in most industries and produce similar (but possibly differentiated) products. To avoid the result that absent distortions all factors flow to the province and sector with the highest TFP level, we assume that the goods across sectors and regions are imperfect substitutes, i.e., positive ϕ and σ.[2]

2.1. Factor allocation and aggregate TFP

Let $L_i = L_{in} + L_{is}$ and $K_i = K_{in} + K_{is}$ be the employment and capital stock in province i and $L = \sum_{i=1}^{m} L_i$ and $K_i = \sum_{i=1}^{m} K_i$ be the total employment and total capital stock. Let $l_{j|i} = L_{ij}/L_i$, $k_{j|i} = K_{ij}/K_i$, $l_i = L_i/L$, and $k_i = K_i/L$ be the shares of employment and capital. Factor allocation across provinces and sectors is determined by a set of these shares, $\{l_i, k_i, l_{j|i}, k_{j|i}\}_{i=1,\ldots,m;\, j=n,s}$, which we simply call an allocation. For a given set of province-sector specific TFPs, A_{ij}, $i = 1, \ldots, m$, $j = n, s$, the following two equations show how we can calculate the provincial and aggregate TFP for any given allocation:

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

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

[1] Using factor shares of US industries and the industry composition of each Chinese province and sector, we calculated the weighted average factor shares of Chinese provinces and sectors. Average labour shares are very similar across provinces, and slightly higher in the state sector than in the non-state sector. Details on the calculation are provided in the supplementary material. We will discuss the implication of relaxing the equal factor elasticity assumption in Section 6.

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

We call the allocation that maximizes the aggregate TFP (or, equivalently, the aggregate output) the efficient allocation and the corresponding aggregate TFP the efficient TFP. If there are factor market distortions, the actual allocation may deviate from the efficient allocation and the actual aggregate TFP may be lower than the efficient TFP. We use the resulting TFP loss as a measure of the cost of factor market distortions.

In the rest of this section, we will discuss the efficient allocation, the competitive allocation under factor market distortions, and the identification and measurement of the distortions.

2.2. Efficient allocation and TFP losses from distortions

The efficient allocation is the solution to the following social planner's problem:

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

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

$$\sum_{i,j} L_{ij} = L, \tag{4}$$

$$\sum_{i,j} K_{ij} = K. \tag{5}$$

Proposition 1. *For any given L and K, the allocation 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

$$\pi_{j|i} = \left(\frac{A_{ij}}{A_i^*}\right)^{\frac{1-\phi}{\phi}} = \frac{A_{ij}^{\frac{1-\phi}{\phi}}}{A_{is}^{\frac{1-\phi}{\phi}} + A_{in}^{\frac{1-\phi}{\phi}}},$$

$$\pi_i = \frac{\omega_i^{\frac{1}{\sigma}} (A_i^*)^{\frac{1-\sigma}{\sigma}}}{\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} (A_i^*)^{\frac{1-\sigma}{\sigma}}},$$

and

$$A_i^* = \left[A_{is}^{\frac{1-\phi}{\phi}} + A_{in}^{\frac{1-\phi}{\phi}}\right]^{\frac{\phi}{1-\phi}}.$$

Proof. All proofs of propositions in this paper are given in the supplementary material.[3] □

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 aggregate TFP is

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

For any given allocation and the associated aggregate and provincial TFP A and A_i, we can then measure proportional TFP losses due to distortions in the aggregate and in a province as follows:

$$D = \ln\left(A^*/A\right) \quad \text{and} \quad D_i = \ln\left(A_i^*/A_i\right).$$

[3] Also available online at: http://www.economics.utoronto.ca/xzhu/paper/BTZAppendix.pdf.

2.3. Factor allocation in a competitive market with distortions

We consider three distortions: province-specific output wedges and sector-province specific capital and labour wedges. While there are other equivalent ways of introducing distortions, our choice is motivated by the empirical evidence on province-sector differences in returns to labour and capital and geographical differences in prices that have been documented by the references we discussed in the introduction.

2.3.1. Firms' problem

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

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

which implies the following first order conditions:

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

Here τ_i^y is a wedge between marginal cost and marginal revenue of using Y_i in aggregate production. We will simply call it the output wedge of province i.

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

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

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

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

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

and

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

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

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

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

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

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

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

Proposition 2. *Given any set of positive wedges* $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\dots,m;\ j=n,s}$, *let*

$$\widetilde{\tau}_{ij}^l = \tau_i^y \tau_{ij}^l, \qquad \widetilde{\tau}_{ij}^k = \tau_i^y \tau_{ij}^k,$$

$$\widetilde{A}_{ij} = \frac{A_{ij}}{\widetilde{\tau}_{ij}^{la} \widetilde{\tau}_{ij}^{k1-a}}, \qquad \widetilde{A}_i = \big[\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}}\big]^{\frac{\phi}{1-\phi}},$$

$$\widetilde{\tau}_i^l = \left(\frac{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{is}^{l-1} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{in}^{l-1}}{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}}}\right)^{-1}, \qquad \widetilde{\tau}_i^k = \left(\frac{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{is}^{k-1} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{in}^{k-1}}{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}}}\right)^{-1},$$

and

$$\widetilde{\tau}^l = \left(\frac{\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_i^{l-1}}{\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}}}\right)^{-1}, \qquad \widetilde{\tau}^k = \left(\frac{\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_i^{k-1}}{\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}}}\right)^{-1}.$$

Then, the competitive allocation implemented by the set of wedges is uniquely determined by the following equations:

$$l_{j|i} = \frac{\widetilde{A}_{ij}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{ij}^{l-1}}{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{is}^{l-1} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{in}^{l-1}}, \qquad k_{j|i} = \frac{\widetilde{A}_{ij}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{ij}^{k-1}}{\widetilde{A}_{is}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{is}^{k-1} + \widetilde{A}_{in}^{\frac{1-\phi}{\phi}} \widetilde{\tau}_{in}^{k-1}},$$

and

$$l_i = \frac{\omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_i^{l-1}}{\sum_{i'=1}^m \omega_{i'}^{\frac{1}{\sigma}} \widetilde{A}_{i'}^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_{i'}^{l-1}}, \qquad k_i = \frac{\omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_i^{k-1}}{\sum_{i'=1}^m \omega_{i'}^{\frac{1}{\sigma}} \widetilde{A}_{i'}^{\frac{1-\sigma}{\sigma}} \widetilde{\tau}_{i'}^{k-1}}.$$

Furthermore, the corresponding provincial and aggregate TFP are given by the next two equations:

$$A_i = \widetilde{A}_i \widetilde{\tau}_i^{la} \widetilde{\tau}_i^{k1-a},$$

and

$$A = \left[\sum_{i=1}^m \omega_i^{\frac{1}{\sigma}} \widetilde{A}_i^{\frac{1-\sigma}{\sigma}}\right]^{\frac{\sigma}{1-\sigma}} \widetilde{\tau}^{la} \widetilde{\tau}^{k1-a}.$$

Proposition 2 shows how one can calculate the competitive allocation and corresponding provincial and aggregate TFP for any given set of wedges. The proposition also shows that the competitive allocation is a function of the product of output wedges and factor market wedges, which implies that the output wedges cannot be separately identified by using the factor allocation alone. With information on provincial price levels, however, both output wedges and factor market wedges can be identified up to a scalar.

2.4. Identification of wedges

Proposition 3. *Let* $(P_1, \dots, P_m)$ *be an arbitrary vector of positive numbers. For any allocation* $\{l_i, k_i, l_{j|i}, k_{j|i}\}_{i=1,\dots,m;\ j=n,s}$, *there exists a set of wedges such that the allocation is the competitive allocation implemented by the set of wedges and that* P_i/P_j *is the equilibrium relative price between province i and province j for any* $i, j = 1, \dots, m$. *Two sets of wedges* $\{\tau_i^y, \tau_{ij}^l, \tau_{ij}^k\}_{i=1,\dots,m;\ j=n,s}$ *and* $\{\theta_i^y, \theta_{ij}^l, \theta_{ij}^k\}_{i=1,\dots,m;\ j=n,s}$ *implement the same competitive allocation and the same relative prices across provinces 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* $\theta_{ij}^k = \gamma\theta_{ij}^k$.

Proposition 3 shows that we can identify the wedges (up to a scalar) from the actual allocation of labour and capital and the provincial price levels. More specifically, from Eqs. (11) and (12), we have

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

$$\tau_{ij}^k \propto \frac{P_{ij} Y_{ij}}{K_{ij}}, \tag{14}$$

and from (6),

$$\tau_i^y \propto P_i^{-1} \omega_i \left(\frac{P_i Y_i}{P_i}\right)^{-\sigma}. \tag{15}$$

From Proposition 2 we know that factor allocation is not affected by any proportional change in wedges that is common across all province and sectors. So we can simply set the labour and capital wedges as average value products of labour and capital, respectively. Similarly, we can set the output wedge to be the term on the right-hand side of Eq. (15).

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 sectors are required. We consider only *non-agricultural* sectors of China's economy and, therefore, all aggregate variables in the model correspond only to non-agricultural data. Unfortunately, the NBS (National Bureau of Statistics) does not provide information for all the key variables we need, and for others there are measurement issues. Consequently, we construct our own unique panel data set that spans the period between 1985 and 2007 and covers 27 out of 31 provinces in mainland China.[4] This section highlights key procedures and sources.[5]

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.[6] 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, half of which was out of province. Third, employed persons include those unemployed. Fourth, employment in the primary (non-primary) sector is likely overstated (understated). And fifth, employment in the state sector is often not reported directly as state employment.

We use census micro-data records from 1982, 1990, 1995, 2000, and 2005 to deal with the first three problems.[7] 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.[8] Finally, from 1993 onwards, some of the former state-owned firms have been reclassified as shareholding corporations. We include employment in these corporations as state employment.

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-agricultural sectors 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.[9]

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 after 2005, fixed investment by limited liability corporations is also reported separately. Investments by these corporations are added to that by the state sector.[10] 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.[11] Our estimates of annual real fixed investment are then used to calculate capital stock in subsequent years.

These totals are rescaled proportionately across provinces so that the total state and non-state capital stocks equal the total national levels as determined by Brandt and Zhu (2010). We perform this re-scaling since, beginning in the mid-to-late

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4 Chongqing, which was part of Sichuan until 1997, is merged with Sichuan; Tibet, Hainan, and Hunan are excluded for missing data; for a number of provinces (Tianjin and Inner Mongolia, mainly) we are missing selective information between 1978 and 1984, and so results are only reported for the 1985–2007 period.

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

6 "Employed persons" is distinct from "staff and workers", which only cover part of the urban workers.

7 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.

8 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.

9 On data issues, see Holz (2009), Holz (in press) and Ortik (2011).

10 These subcategories of investment are found in the Fixed Asset Investment Yearbooks of China.

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

1990s, China privatized many of its small and medium-sized SOEs. We utilize information on the total number of SOEs, and the number of firms that were privatized each year to adjust the national capital stock in the state and non-state sectors. Lacking firm-level information on the capital stock, we assume that the privatized firm's share of the total state sector capital stock is proportional to their share of the total number of SOEs. Since these firms were typically small to medium in size, this procedure likely over-estimates the change in assets associated with the privatization. Information on privatization of SOEs is not available by province. Our rescaling of provincial capital stocks to match aggregate figures effectively assumes that privatization of state sector assets in a province is proportional to the province's share of total state sector assets.

3.3. GDP and GDP deflators

China's NBS annually reports nominal GDP levels and real GDP growth for each province but not real GDP levels. These are reported separately for agriculture, manufacturing, and service sectors. To construct real non-agricultural GDP for each of China's provinces between 1978 and 2007, we use information on nominal non-agricultural GDP, real non-agricultural GDP growth rates, and price level differences in 1990. We first proportionately re-scale reported nominal non-agricultural GDP values in every year such that the sum across provinces equals the national total. Reported year-over-year real growth rates for each province are used to construct the growth rate of each province's GDP deflator. Specifically, this is given by the ratio of the gross nominal growth to the real growth rates. To capture level differences in our base year (1990), the 1990 GDP deflator is set equal to each provinces' cost of a common basket of goods relative to the national average. The costs of these baskets are taken from Brandt and Holz (2006).

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 approximate the relative GDP-per-worker by 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.[12] We test our estimation method by applying it to China's manufacturing sector for the period between 1998 and 2007, during which we have detailed firm level data and therefore can calculate value-added by ownership directly. For the whole period, the average state sector's share of value added is 0.53 and the average share implied by our estimation is 0.52.

4. Empirical analysis

In this section, we use the model of Section 2 with data described in Section 3 to estimate the magnitude of, and TFP losses associated with, factor market distortions in China. To be clear, we are investigating only non-agricultural activities in China. References to sectors should also be understood as "state" and "non-state" sectors, not particular industries.

4.1. Parameter choices

In addition to the provincial weights ω_i, $i = 1, \dots, m$, there are three parameters in the model: the 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 factor market distortions, however, the labour share is generally not equal to 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 are no available estimates of ϕ and σ in the literature. We choose 0.67 as the value for both parameters. This implies that the elasticities of substitution across provinces and between sectors are both 1.5, which is the value commonly used in the international real business cycle literature 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 the TFP loss from misallocation. With higher values for these elasticities (and therefore lower values for ϕ and σ), the estimated TFP loss in China would be larger.

For the provincial weights, we choose ω_i such that Eq. (6) holds on average over the entire period of 1985–2007 if there were no product market distortions. Specifically, we set ω_i as follows:

$$\omega_i = \frac{1}{23} \sum_{t=1985}^{2007} \left(\frac{P_i(t) Y_i^{\sigma}(t)}{\sum_{i'=1}^{m} P_{i'}(t) Y_{i'}^{\sigma}(t)} \right). \tag{16}$$

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

[12] Total and state-sector employment and wages, by province, for years prior to 1995 are taken from China Regional Economy Statistics. For later years, we utilize the Labour Statistics Yearbook of China and the Statistical Yearbook of China.

Table 1
Total factor productivity for selected years by province and sector.

Province	Aggregate			State			Non-state		
	1985	1997	2007	1985	1997	2007	1985	1997	2007
Anhui	0.353	0.854	1.545	0.033	0.024	0.036	0.227	0.676	1.338
Beijing	0.574	1.047	1.976	0.304	0.397	0.153	0.052	0.152	1.221
Fujian	0.406	1.154	1.946	0.037	0.060	0.087	0.216	0.734	1.327
Gansu	0.317	0.622	1.035	0.090	0.153	0.158	0.107	0.203	0.525
Guangdong	0.362	0.969	1.925	0.041	0.074	0.077	0.177	0.550	1.363
Guangxi	0.364	0.699	1.198	0.099	0.064	0.076	0.124	0.370	0.789
Guizhou	0.237	0.432	0.790	0.174	0.019	0.058	0.023	0.339	0.559
Hebei	0.356	0.961	1.395	0.031	0.120	0.078	0.227	0.423	0.924
Heilongjiang	0.454	0.810	1.470	0.122	0.239	0.219	0.141	0.204	0.735
Henan	0.303	0.687	1.351	0.035	0.037	0.078	0.176	0.452	0.892
Hubei	0.345	0.846	1.611	0.034	0.060	0.089	0.243	0.537	1.151
Inner Mongolia	0.354	0.714	1.500	0.094	0.129	0.092	0.157	0.284	1.208
Jiangsu	0.407	1.021	2.047	0.044	0.083	0.032	0.215	0.538	1.732
Jiangxi	0.347	0.731	1.250	0.096	0.039	0.058	0.097	0.491	0.904
Jilin	0.354	0.736	1.504	0.076	0.159	0.172	0.121	0.251	0.824
Liaoning	0.554	0.950	1.895	0.072	0.145	0.131	0.322	0.409	1.192
Ningxia	0.340	0.622	0.895	0.117	0.220	0.086	0.086	0.125	0.550
Qinghai	0.350	0.596	1.065	0.160	0.251	0.173	0.055	0.114	0.579
Shaanxi	0.270	0.636	1.074	0.119	0.120	0.133	0.047	0.236	0.592
Shandong	0.410	1.117	1.969	0.031	0.108	0.101	0.235	0.564	1.320
Shanghai	0.653	1.400	2.506	0.246	0.239	0.135	0.110	0.520	1.688
Shanxi	0.354	0.746	1.486	0.052	0.096	0.130	0.171	0.370	0.926
Sichuan	0.525	0.702	1.128	0.245	0.089	0.066	0.060	0.330	0.802
Tianjin	0.527	1.166	2.513	0.138	0.216	0.131	0.161	0.472	1.809
Xinjiang	0.339	0.746	1.070	0.150	0.277	0.173	0.052	0.133	0.517
Yunnan	0.327	0.675	0.874	0.065	0.111	0.060	0.129	0.284	0.628
Zhejiang	0.521	1.296	2.122	0.039	0.042	0.081	0.284	0.943	1.565
By region									
East	0.454	1.090	1.971	0.187	0.210	0.102	0.221	0.615	1.437
Middle	0.339	0.773	1.466	0.064	0.079	0.091	0.200	0.526	1.090
Northeast	0.488	0.867	1.692	0.098	0.193	0.182	0.258	0.345	1.025
West	0.384	0.661	1.034	0.185	0.175	0.124	0.086	0.295	0.680

4.2. Measuring TFP by province and sector

To measure distortions, we need to have measures of province- and sector-specific TFP, A_{ij}, for all provinces and sectors. To measure this directly, we need province- and sector-specific deflators. However, we only have deflators by province. Thus, we need to adjust for the sectoral price differences in each year. Using a method similar to Hsieh and Klenow (2009), we infer the price information from nominal value-added shares. With the CES aggregate production functions, it can be shown that the prices satisfy the following equations:

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

Thus, we can calculate the real value-added for each sector and province in the following way[13]:

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

We use this measure of real value-added by sector and province, along with employment and capital data, to estimate TFP from Eq. (1).

Table 1 lists the TFP of the non-state and state sectors for each of the 27 provinces in 1985, 1997 and 2007. Fig. 1 also shows box plots of non-agricultural TFP of the state and the non-state sectors across the 27 provinces for all years between 1985 and 2007. In general, the TFP levels in the non-state sector are higher than those in the state sector and the gaps have increased over time. There are also significant differences in TFP across provinces – especially in the state sector. These TFP differences imply that the efficient allocation should have more capital and labour be allocated to the non-state sector and to provinces with higher TFP levels. Deviations from the efficient allocation will lead to lower TFP.

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[13] 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. In the case of imperfect substitution, however, the two are not the same.

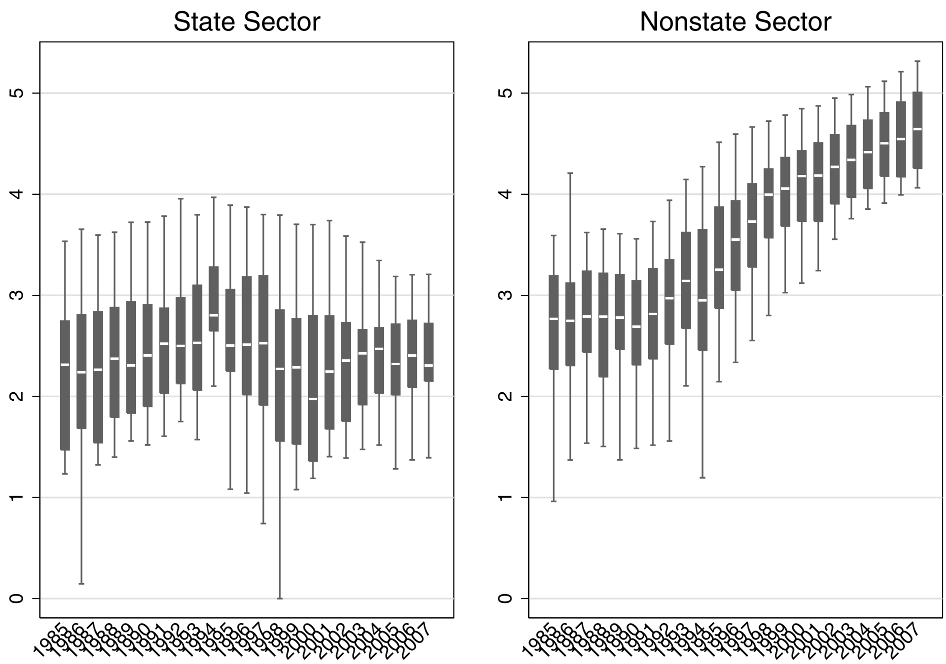

Fig. 1. Box plot of total factor productivity. *Note*: This box plot illustrates, for each year and sector, the log provincial TFP. All values are rescaled relative to the lowest observed value. The dark boxes give the inter-quartile range across provinces for a given year. The median is the white line within each dark box. The bottom and top ends of the thin whisker mark the 5th and 95th percentiles, respectively. The figure illustrates the generally constant TFP in the state sector in all provinces. In the non-state sector, TFP is continuously increasing and the cross-province dispersion is generally declining.

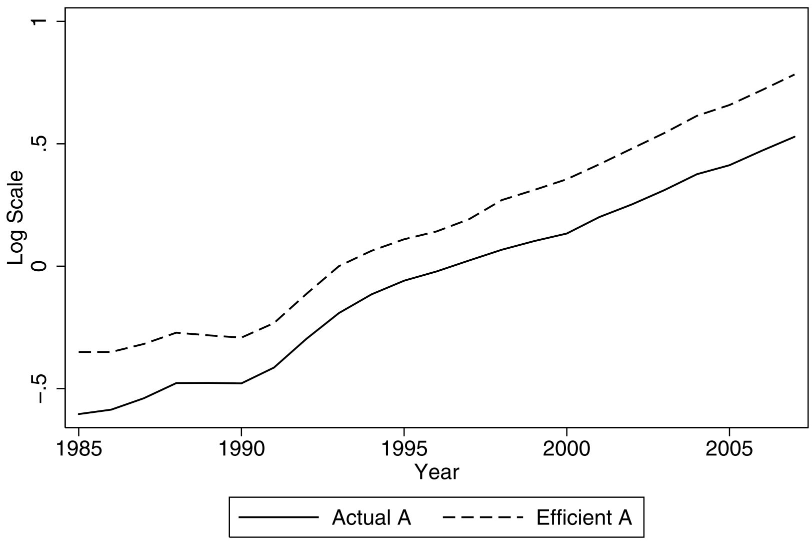

Fig. 2. Productivity over time. *Note*: This plots the observed aggregate non-agricultural TFP in China over time with the model-implied efficient TFP. The increasing gap between the two lines illustrates the aggregate effect of the distortions.

4.3. The evolution of factor market distortions over time

We now examine the impact of misallocation of factors on aggregate non-agricultural TFP. Fig. 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 0.20. In other words, on average the actual TFP is around 20% 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 0.24 in 1985, 0.18 in 1997 and 0.23 in 2007.

Table 2
Distortions and TFP growth over time, aggregate.

Period	1985–2007	1985–1997	1997–2007
Average distortion	0.202	0.195	0.209
Average efficient TFP growth	6.46%	6.44%	6.49%
Average actual TFP growth	6.52%	6.95%	5.99%
Impact of distortions: actual − efficient	0.06%	0.52%	−0.50%

Table 3
Distortions and TFP growth over time, by region.

Region	Average within province distortion	Average actual TFP growth	TFP growth differential: actual − efficient		
	1985–2007	1985–2007	1985–2007	1985–1997	1997–2007
East	0.087	6.60%	−0.03%	0.36%	−0.51%
Middle	0.145	6.57%	0.24%	0.89%	−0.54%
Northeast	0.139	5.83%	0.07%	0.56%	−0.52%
West	0.158	4.97%	−0.17%	0.41%	−0.85%

Table 4
Robustness: Impact of distortions.

Scenario	Average distortion	TFP growth differential: actual − efficient		
	1985–2007	1985–2007	1985–1997	1997–2007
Baseline	0.20	0.06%	0.52%	−0.50%
$\sigma^{-1} = 3$	0.26	−0.06%	0.39%	−0.60%
$\phi^{-1} = 3$	0.21	0.14%	0.63%	−0.46%
$a = 0.5$	0.23	0.21%	0.96%	−0.69%
Equal w_i	0.26	−0.06%	0.37%	−0.58%

Table 2 shows the average level of distortions and 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 0.52% higher than the growth rate of the efficient TFP. In other words, improvements in factor allocation in the first sub-period contributed about half a percent to annual aggregate TFP growth. In the last decade, however, the trend was reversed: The average annual growth rate of the actual TFP was 0.50% lower than that of the efficient TFP. This implies that overall factor market distortions increased during the second sub-period, offsetting almost all of the efficiency gains from reduced distortions in the first sub-period.

The level of within-province distortions, as measured by $D_i = \ln(A_i^*/A_i)$, varies significantly across provinces. Table 3 shows the average level of within-province distortions, average actual TFP growth and the impact of the distortions on TFP growth for the four regions in China: East, Middle, Northeast and West. For the entire period, the Eastern provinces have the highest average TFP growth rate (6.6%) and the lowest average level of distortions (0.087). In contrast, the Western provinces have the lowest TFP growth rate (4.97%) and the highest level of distortions (0.158). However, the impacts of the change in distortions on TFP growth at the regional level are similar to that at the national level. All four regions experienced a reduction in distortions in the first sub-period followed by an increase in the second sub-period. The provinces that have higher average level of distortions are also the provinces that experienced larger increases in distortions in the second sub-period.

To see if our results above are robust to choices of parameter values, Table 4 reports both the average level of distortions and the impact of the change in distortions on the difference between the efficient and actual TFP growth rates for the benchmark case reported above (i.e., $\sigma^{-1} = 1.5$, $\phi^{-1} = 1.5$, $a = 0.67$ and province weights calibrated according to Eq. (16)) and four other cases: (1) $\sigma^{-1} = 3$, (2) $\phi^{-1} = 3$, (3) $a = 0.5$ and (4) equal provincial weight, respectively. Our benchmark parameter values are chosen conservatively so that we do not overestimate the TFP losses associated with distortions. As expected, the measured effect on TFP of distortions increases when we increase either the elasticity of substitution across provinces or the elasticity of substitution between the two sectors. When the labour elasticity is lowered or capital elasticity is increased, the misallocation of capital between the state and non-state sectors becomes more important for the aggregate distortions and the associated TFP loss also increases. Finally, the provincial weights that we calibrated assume that the average output wedge is zero and therefore implies TFP falls only slightly due to product market distortions. Constant provincial weights result in higher TFP losses from product market distortions. In all cases, however, 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 impact of different types of distortions on the aggregate TFP by conducting a series of counterfactual experiments using the model presented in Section 3. To evaluate the impact of within-province distortions in capital allocation, for example, we set the capital wedges of both the state and non-state to the average wedge 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 wedges 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 wedges 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 wedges.
  - No between-province distortion in capital allocation: Eliminating the cross-province differences in capital wedges.
  - No between-province distortion in labour allocation: Eliminating the cross-province differences in labour wedges.
  - 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

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

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. Fig. 3(a) 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 constant over time, suggesting that the changes in overall distortion over time were mainly due to changes in within-province distortions.

4.4.1. Comparison with the United States

To put our measures of distortions in perspective, we compare the magnitude of China's TFP losses from between-province distortions with what a similar method finds for the United States. While we have no data sufficient to estimate within-state distortions between various sectors (and no comparable state-owned/non-state distinction), we can estimate the magnitude of the between-state factor market distortions. Specifically, we follow the main model structure presented earlier and use

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

as the efficient level of US productivity. We presume for this exercise there is no within-state distortion; that is, $A_i^* = A_i$. Our measure for the between-state distortion is as before: $D = -\ln(A/A^*)$, where the actual aggregate TFP, A, is the aggregate GDP of $Y = [\sum_{i=1}^m \omega_i (Y_i)^{1-\sigma}]^{\frac{1}{1-\sigma}}$ relative to the aggregate input bundle $(\sum_{i=1}^m L_i)^{\alpha} (\sum_{i=1}^m K_i)^{1-\alpha}$.

We use data on state-level employment and GDP from the Bureau of Economic Analysis. For the real value of state capital stock, we use the state-by-state data of Garofalo and Yamarik (2002). Assuming a labour share (α) of 0.67, state-level TFP can be calculated in the standard way: $A_i = Y_i / L_i^{\alpha} K_i^{1-\alpha}$. For comparison with our analysis for China, we assume the same substitution parameter value of $\sigma^{-1} = 1.5$. In order to measure the state-specific output weights, we presume product markets in the United States face no distortions. In that case, state-specific price levels – for which we have one year of data for 2005 from Aten (2008)[14] – can be used to back-out the weights with the following formula:

$$\omega_i = \frac{P_i \left(\frac{Y_i^{\text{nominal}}}{P_i}\right)^{\sigma}}{\sum_{i=1}^m P_i \left(\frac{Y_i^{\text{nominal}}}{P_i}\right)^{\sigma}}.$$

We report the results of this exercise in Fig. 4, which clearly finds that between-state distortions in the United States are small. US productivity is approximately 2% lower than the efficient level, moreover, it is relatively stable over time

[14] The official state-level real GDP series from the BEA uses a national price index to deflate each state's nominal GDP. Aten (2008), with the Regional Economics Directorate of the BEA, infers and reports prices and real GDP data using state-specific prices.

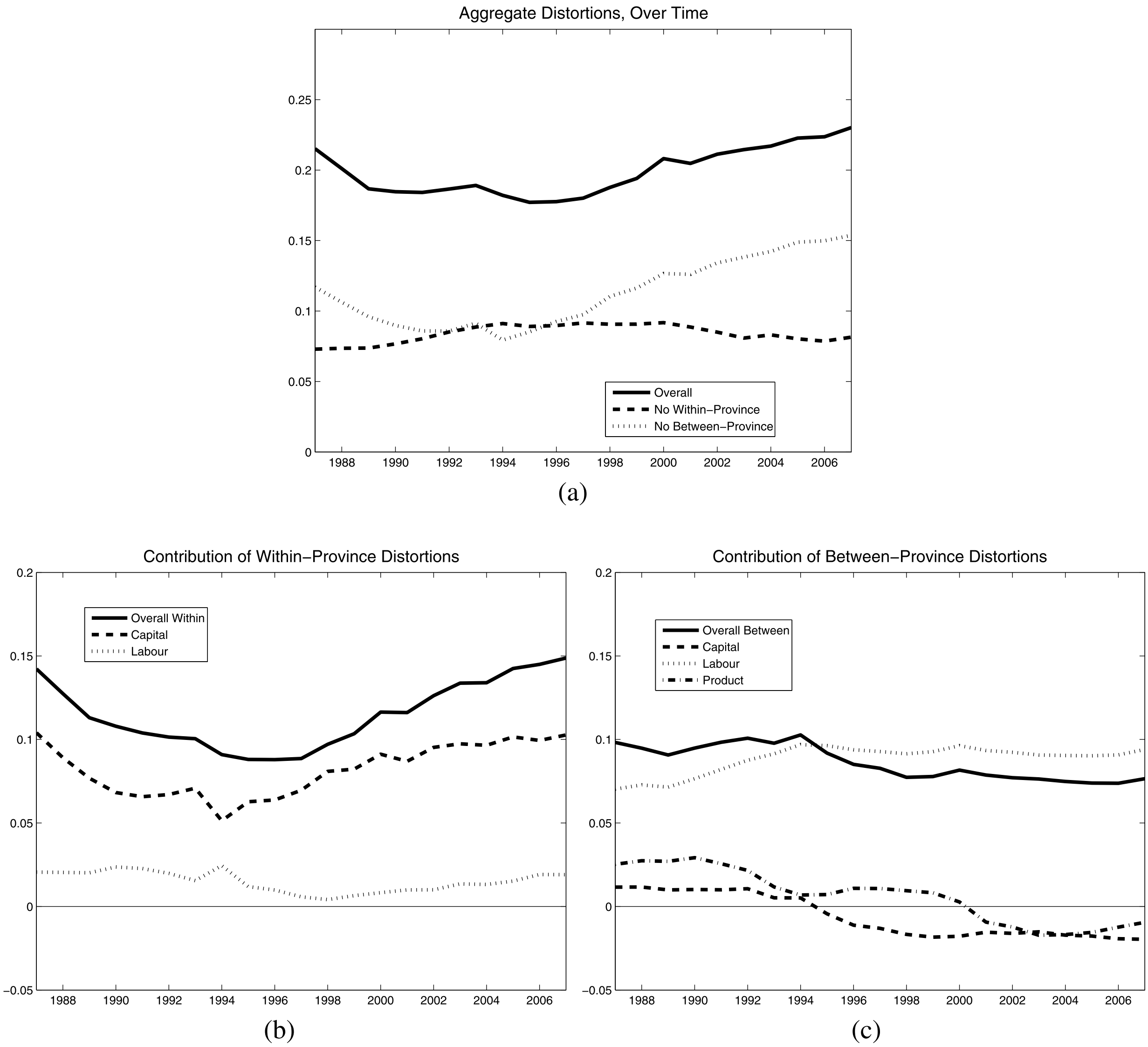

Fig. 3. Distortions within and between provinces of China, 1985–2007. *Note*: Panel (a) illustrates the aggregate non-agricultural TFP loss from overall distortions, the TFP loss from within-province distortions, and the TFP loss from between-province distortions. Panel (b) decomposes the within-province distortions into capital and labour market distortions. Panel (c) decomposes the between-province distortions into capital, labour, and product market distortions.

(varying between 1.5% and 3.5%). The corresponding loss in TFP from between-province distortions in China (nearly 10%) is significantly larger than in the United States.

4.4.2. Within-province distortions

To quantify the contribution of within-province distortions to aggregate distortion, we use the following measure:

$$d_w = D - D_b = \ln(A_{nw}/A).$$

Distortions within a province take the form of labour or capital market distortions between the state and non-state sectors. Let A_{nwl} and A_{nwk} be the aggregate TFP when there is no within-province labour and capital market distortion, respectively. We also 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. Fig. 3(b) displays 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

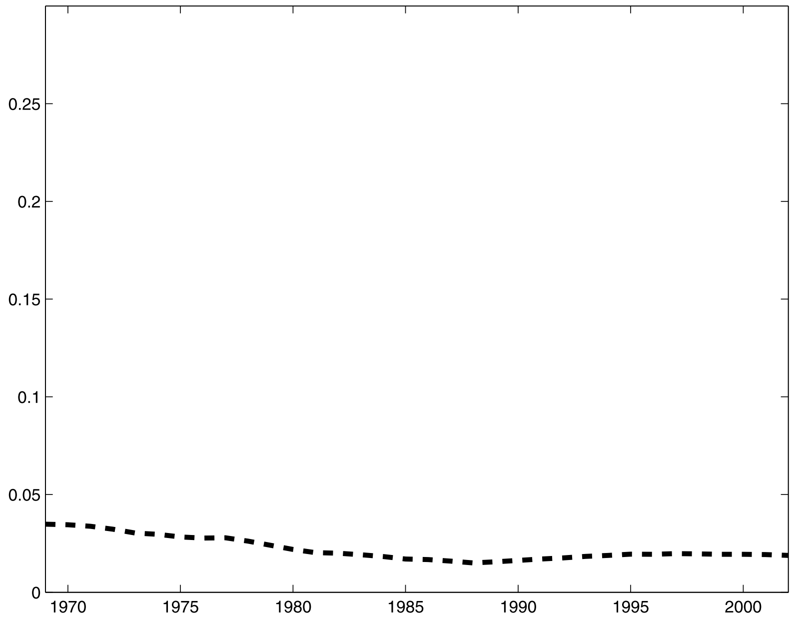

Fig. 4. Between-state distortions through time for the United States. *Note*: This figure uses state-level data from the US to infer the TFP loss from between-province (or state in this case) distortions in labour and capital markets. For comparison with China, see the dashed line in Fig. 3(a).

variation in the contribution of within-province distortions to the 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.

4.4.3. Between-province distortions

Similarly, we can also measure the contribution of between-province distortions by

$$d_b = D - D_w = \ln(A_{nb}/A)$$

and 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

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

as measures of the contribution to aggregate distortion of between-province labour, capital and product market distortions, respectively. Fig. 3(c) 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. The contribution of between-province product market distortions has also been small and declining over time. The most important source of between-province distortions is the labour market friction. Furthermore, Fig. 3(c) shows that the TFP losses from between-province labour market distortions has not declined over time.

4.5. Summary of empirical results

For the period 1985–2007, we find that factor market distortions reduced the aggregate non-agricultural TFP conservatively by about 20%. TFP losses from misallocation declined until mid-1990s, then rose afterwards. Contributions of between-province and within-province distortions are of comparable magnitude. Between-province distortions lowered TFP by a roughly constant amount for the entire period and mostly comes from wedges in labour markets. In contrast, within-province distortions results in TFP losses that varied over time, declining between 1985 and 1997, then rising sharply after 1997. Nearly all of the 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, the TFP losses from between-province labour market distortions has remained remarkably constant over time. Why has the effect of labour market distortions not declined? What drives the changes in capital market distortions? We address these questions in the next section.

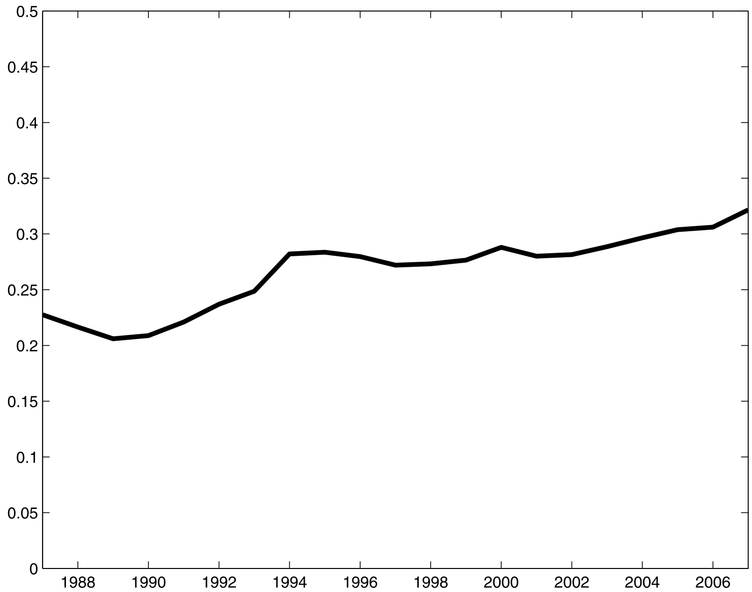

Fig. 5. Cross-province dispersion in TFP. *Note*: This figure plots the variance in log TFP across provinces over time.

5. Discussions

5.1. Why no decline in between-province labour market distortions?

Since the mid-1990s, China has experienced a massive labour migration across provinces, most of which is going from low TFP (middle and western) provinces to high TFP (coastal) provinces. This kind of reallocation should help to reduce the differences in returns to labour across provinces and therefore the between-province labour market distortions. Yet, between-province labour market distortions still have a significant negative effect on TFP. One explanation for this finding is the rising dispersion in TFP across provinces. As the differences in TFP between provinces widen, more labour should be reallocated to the more productive provinces in order to reduce the differences in labour returns. Fig. 5 plots the cross-province variance of ln(TFP) over time. In recent years, as the cross-province labour reallocation increased, the cross-province dispersion in TFP has also increased. How the dispersion in returns to labour behaves 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 effect of labour market distortions remained high despite huge flows of labour crossing provincial boundaries.

5.2. What drives the changes in capital market distortions?

Fig. 3(c) shows that the TFP losses from between-province capital distortions has declined over time. The within-province distortions in the allocation of capital between the state and non-state sectors, however, has in recent years lowered TFP by more. Why? Here we provide evidence showing that it may be partly due to the Chinese government's regional policies.

Fig. 6(a) 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 of the coastal provinces, had the highest labour productivity while the Western region's labour productivity was the lowest. Around that time, many economists and policy makers argued that this gap in performance was a product of the central government's preferential policies towards the Eastern provinces which allowed them to attract more investment. To reduce the disparity, it was argued that the central government should adopt policies to direct more investment to the Western provinces. Thus, a new policy initiative, Develop the Great West, was introduced in the late 1990s by the central government.

Was the lower level of development in the Western region a result of capital scarcity? The answer is no. Fig. 6(b) shows that the Western region actually had the highest capital–output ratio among the four regions. Fig. 6(c) shows that low TFP is the main reason for the low output per worker in the West. The Develop the Great West policy worked in one aspect: The Western region experienced significant increases in the 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.

The reason for this policy failure is clear: 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 Figs. 6(e) and 6(f) for TFP and the capital–output ratio by sector and region). Thus, misallocation of capital between the state and the non-state sector worsened as a result of the regional development policy and the within-province distortions increased significantly between 1997 and 2007 (see

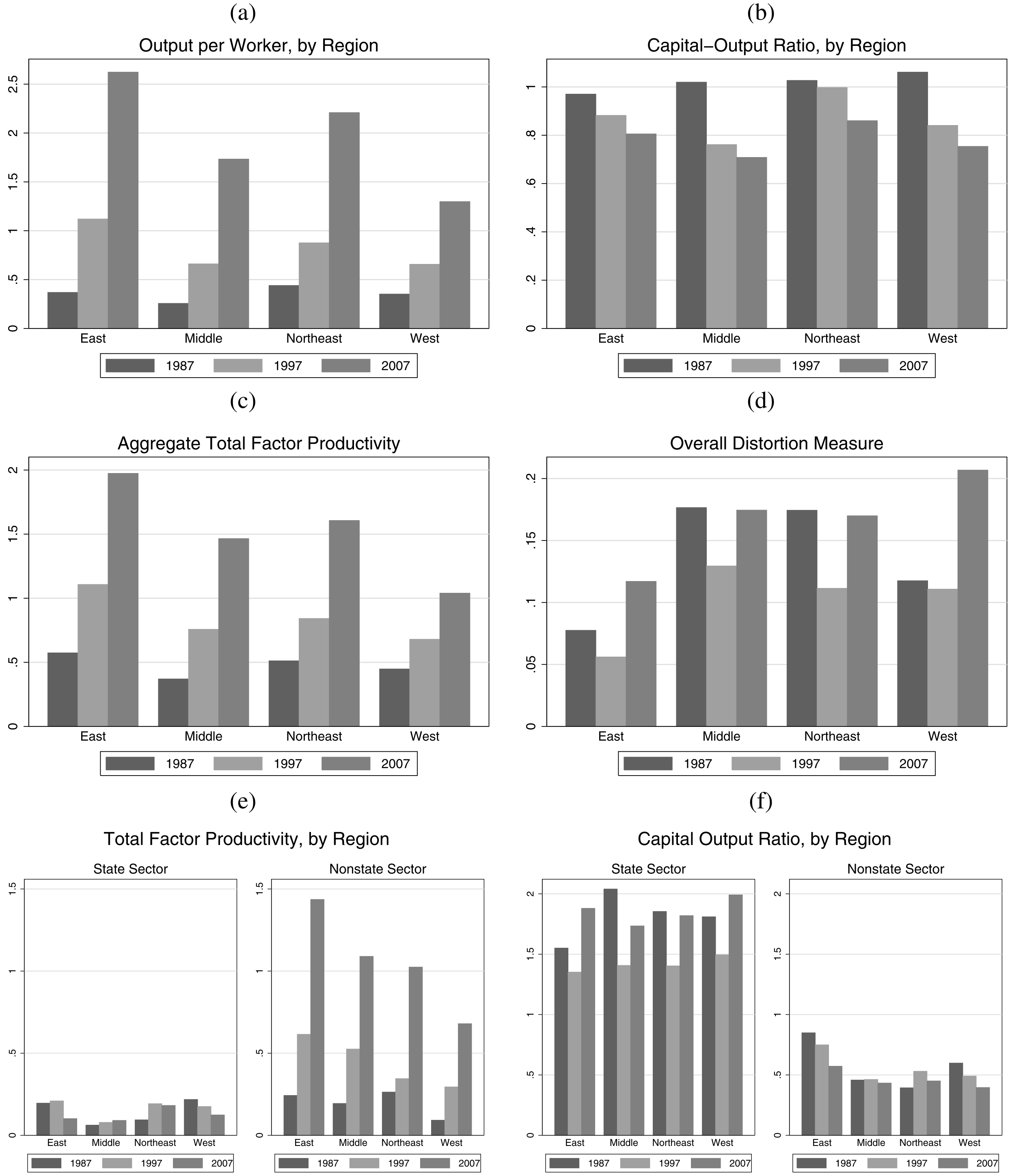

Fig. 6. Comparison by region and sector in China.

Fig. 6(f)). 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 important to note that prior to the 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. Brandt and Zhu (2000) provide a discussion

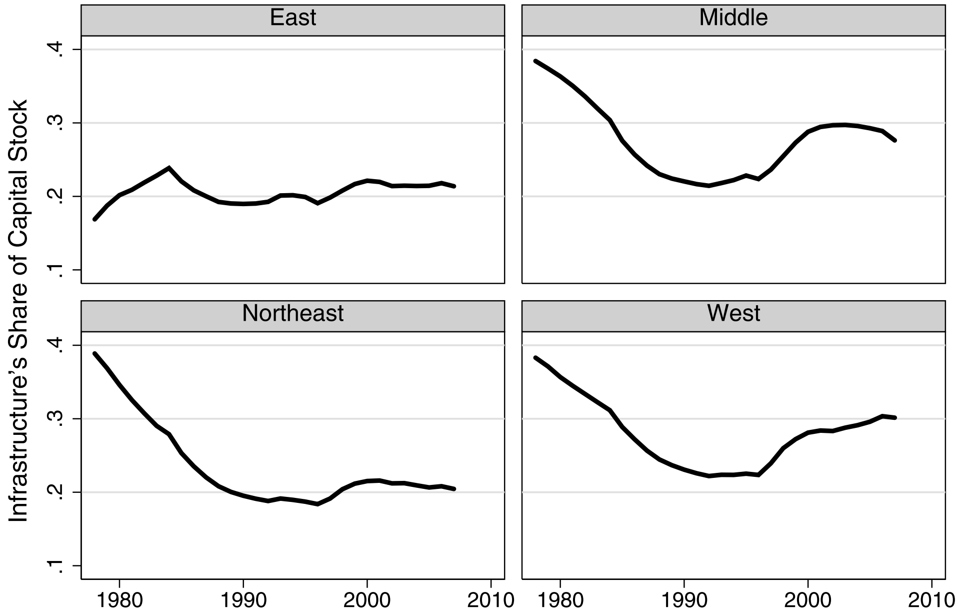

Fig. 7. Infrastructure's share of capital stock.

about the decentralization process that facilitated this movement of capital from the state to non-state sector during this period. 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. The re-centralization of the banking system documented by Brandt and Zhu (2007) may have also contributed to the reversal. Huang (2008) and Walter and Howie (2011) also argue that China's financial sector has become less friendly to the private sector since the mid-1990s.

6. Robustness of the main results

In Section 4.3 we have already shown that our main results are robust to using alternative parameter values in our benchmark model. As discussed in Section 3.2, we also adjust for the impact of privatization in our estimation of state and non-state capital to ensure that our results are not biased due to privatization. In this section we show that our main results still hold if we allow for infrastructure capital, human capital and differences in industry composition between the state and the non-state sectors.

6.1. Infrastructure capital

Since the mid-1990s, an increasing portion of the state sector's investments has gone to infrastructure. It is possible that infrastructure investments have helped to increase output in the non-state sector while the 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.[15]

For each province, we break down capital in the state sector into infrastructure and non-infrastructure capital, denoted 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 $(X_1, \ldots, X_m)$ 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.

Fig. 7 plots infrastructure's share of the 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 more recently in the Western regions. The timing of the increase also coincides with the implementation of the Develop the Great West policy.

[15] The details of the infrastructure model are available from authors upon request.

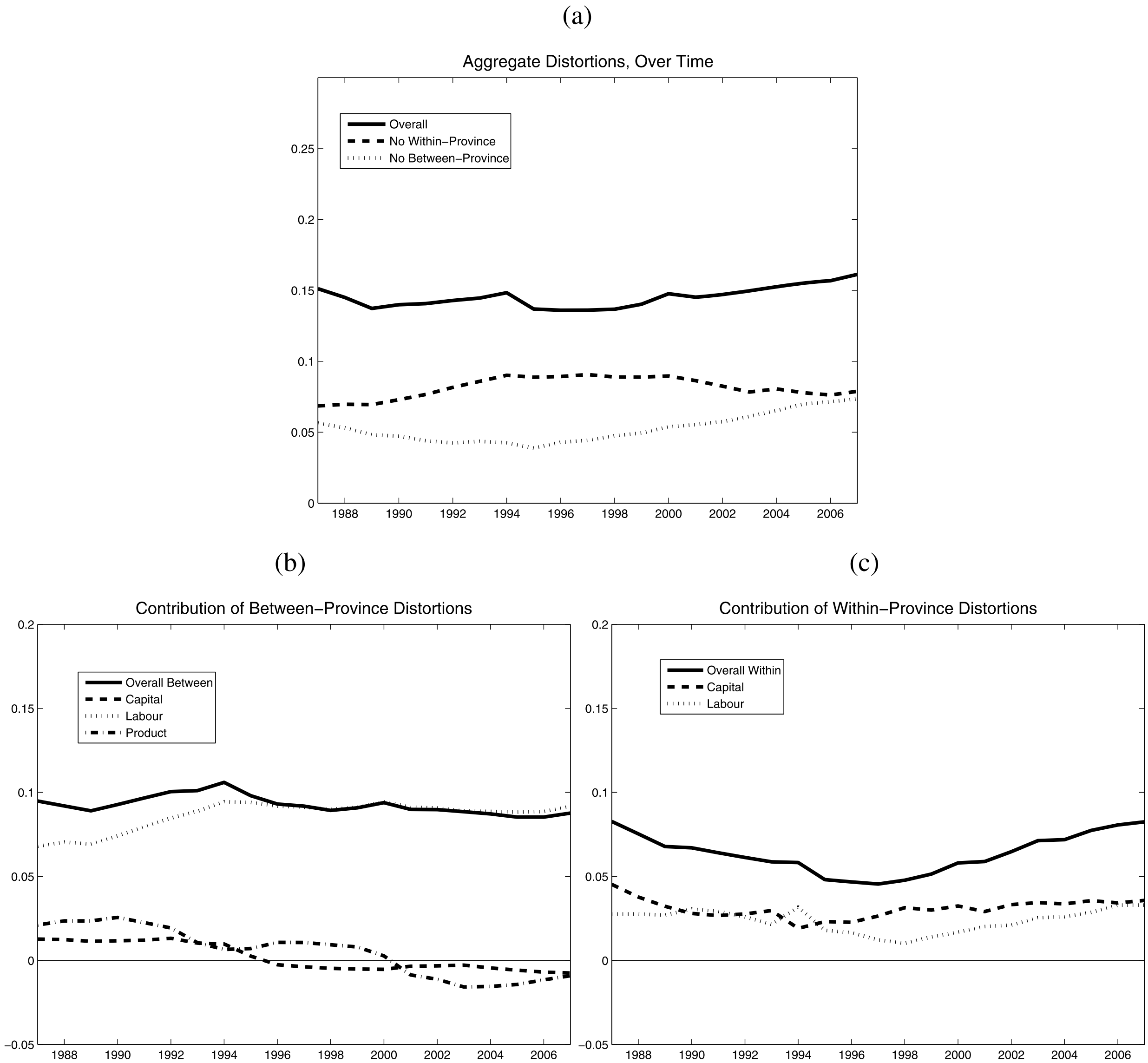

Fig. 8. Distortions between and within provinces of China, infrastructure case. *Note*: These plots are similar to our baseline but with infrastructure capital explicitly accounted for. Panel (a) illustrates the aggregate non-agricultural TFP loss from overall distortions, the TFP loss from within-province distortions, and the TFP loss from between-province distortions. Panel (b) decomposes the within-province distortions into capital and labour market distortions. Panel (c) decomposes the between-province distortions into capital, labour, and product market distortions.

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 optimal infrastructure share in each province will 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. Continuing to set the labour elasticity equal to 0.67, we set the value b to 0.25 so that the model-implied optimal fraction of capital used for infrastructure, $(1-a-b)/(1-a)$, matches the average fraction in the data. The resulting elasticity of infrastructure capital is 0.08.

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. Figs. 8(a)–8(c) plot these measures over time. Because of the breakup of the capital stock into infrastructure and non-infrastructure capital, the output elasticity of non-infrastructure capital is smaller than 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 hold true here: (1) The TFP loss from between-province labour market distortions is significant and relatively

Table 5
Labour shares of output, by sector.

	Non-state	State
1985	56.21%	59.94%
1990	55.70%	60.27%
1995	57.07%	60.40%
2000	56.30%	65.05%
2007	53.38%	68.13%

stable over time; and (2) the TFP loss from within-province capital market distortions is also significant and increased in recent years.

6.2. Human capital

To ensure our measure of between-province distortions in the labour market does not simply reflect spatial or sectoral differences in average human capital, we repeat the main exercises of the paper using human-capital adjusted labour input. We detail the precise procedures used to construct a measure of human capital for each sector and province in the supplementary material. The overall results are generally not altered by using human-capital adjusted labour inputs. The average aggregate distortion over the sample period is slightly lower, just under 0.18 compared to 0.20 in our baseline. The time patterns of the between- and within-province distortions are as before: (1) the TFP loss from between-province distortions is generally constant; and (2) the TFP loss from within-province distortions is initially declining and then rising in recent years. The main contributor to distortions between provinces is still almost entirely the labour market. Likewise, within-province distortions are almost entirely due to the capital market distortions between the state and non-state sectors.

6.3. Industry composition

In all of our analysis so far, we have made the assumption that the state and non-state sectors use technologies that have the same factor elasticities. There is some evidence that, within the manufacturing sector, the state sector has moved towards more capital intensive industries (Song et al., 2011). If this is true for the non-agricultural sector as a whole, then our assumption would lead to an underestimation of returns to capital in the state sector, especially in the later years, and our result of increasing capital market distortions may no longer hold once we allow for differences in industry composition between the two sectors. To examine this issue, we construct estimates of labour-intensity for state and non-state output using labour's share of value-added for corresponding sectors of the United States. Given that product and factor markets are more competitive in the United States, the US shares should more closely correspond to technical factor-elasticities of output. This exercise will determine if the sectoral-composition of state and non-state output differs systematically in a manner that invalidates our baseline assumption of equal factor shares. The details about the calculation are given in the supplementary material.

The results suggest that since the mid-1990s the state sector has become more labour intensive. They also suggest the non-state sectors are slightly less labour intensive and the labour shares are roughly stable over time. We present the implied state and non-state shares for each sector in Table 5. To determine the variation in labour shares across provinces, we carry out a similar exercise as above for 1985 and 1996 using region-specific employment information by sector and by state and non-state. We find the cross-province variation is minor. We also confirm that the state sector is slightly more labour intensive than the non-state sectors.

It is important to note the source of the higher labour share in the state sector. In the US, the health and education sectors both have labour shares in excess of 80%. The state employment of China is significantly concentrated in these sectors, and this concentration is increasing over time. For example, in 2007, 30% of state employment was in health, education, and welfare sectors. In 1985, this was just over 10%. Also extremely labour-intensive is the so-called Public Management and Social Organizations sector (which we map to the government sector of the US), which also has a labour share over 80%. The fraction of total state employment in this sector in China in 2007 was 20%. So, half of state employment is concentrated in highly labour intensive service sector areas. This accounts for the higher state sector labour share overall and the growing share over time.

In summary, we find no evidence that, for the non-agricultural sector as a whole, the industry composition of the state sector has become more capital intensive. If anything, the state sector has become slightly more labour intensive. Thus, our result of increasing capital market distortions is unlikely to change if we were to allow for differences in industry composition between the state and the non-state sectors.

7. Conclusion

In this paper, we examine the impact of the misallocation of resources across provinces and sectors (state versus non-state) on aggregate non-agricultural TFP. Despite significant increases in factor mobility, our analysis suggests that China continues to suffer high TFP losses arising from factor market distortions. After declining during the first decade and a half of reform and contributing positively to aggregate non-agricultural TFP growth, these distortions have increased significantly since 1997, reducing aggregate non-agricultural TFP growth by half a percent a year. By 2007, these distortions were lowering aggregate non-agricultural TFP by at least a quarter. Within province distortions arising from the favoured treatment of the state-sector vis-a-vis the non-state sector are the most important source of these distortions. There is also a marked "regional" dimension to them, with the distortions and the consequent TFP losses 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 capital to these provinces through a highly inefficient state sector. Reversing this troubling trend in the misallocation of capital should be of high priority on the government's agenda of future economic reforms and could be an important potential source of China's aggregate productivity growth in the near future.

Supplementary material

The online version of this article contains additional supplementary material.
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References

Adamopoulos, Tasso, Restuccia, Diego, 2011. The size distribution of farms and international productivity differences. University of Toronto Working Paper No. 441.

Alfaro, Laura, Charlton, Andrew, Kanczuk, Fabio, 2008. Plant-size distribution and cross-country income differences. NBER Working Paper No. 14060.

Aten, Bettina H., 2008. Estimates of state and metropolitan price parities for consumption goods and services in the United States, 2005.

Bai, Chong-En, Hsieh, Chang-Tai, Qian, Yingyi, 2006. The returns to capital in China. Brookings Papers on Economic Activity 37 (2), 61–102.

Banerjee, Abhijit, Duflo, Esther, 2008. Do firms want to borrow more? Testing credit constraints using a directed lending program. MIT Department of Economics Working Paper No. 02-25.

Bartelsman, Eric J., Haltiwanger, John, Scarpetta, Stefano, 2009. Cross-country differences in productivity: The role of allocation and selection. NBER Working Paper No. 15490.

Boyreau-Debray, Genevieve, Wei, Shang-Jin, 2004. Can China grow faster? A diagnosis on the fragmentation of the domestic capital market. IMF Working Paper 04/76, International Monetary Fund.

Boyreau-Debray, Genevieve, Wei, Shang-Jin, 2005. Pitfalls of a state-dominated financial system: The case of China? NBER Working Paper No. 11214.

Brandt, Loren, Holz, Carsten A., 2006. Spatial price differences in China: Estimates and implications. Economic Development and Cultural Change 55 (1), 43–86.

Brandt, Loren, Zhu, Xiaodong, 2000. Redistribution in a decentralizing economy: Growth and inflation cycles in China. Journal of Political Economy 108 (2), 422–439.

Brandt, Loren, Zhu, Xiaodong, 2007. China's banking sector and economic growth. In: Calormiris, Charles (Ed.), China at Cross-Road. Columbia University Press, pp. 86–136.

Brandt, Loren, Zhu, Xiaodong, 2010. Accounting for China's growth. University of Toronto Working Paper No. 394.

Chan, Kam Wing, Henderson, J. Vernon, Tsui, Kai Yuen, 2008. Spatial dimensions of Chinese economic development. In: Brandt, Loren, Rawski, Thomas G. (Eds.), China's Great Economic Transformation. Cambridge University Press, New York.

Dollar, David, Wei, Shang-Jin, 2007. Das (wasted) Kapital: Firm ownership and investment efficiency in China. NBER Working Paper No. 13103.

Donnithorne, Audrey, 1972. China's cellular economy: Some economic trends since the cultural revolution. China Quarterly 52, 605–619.

Garofalo, Gasper G., Yamarik, Steven, 2002. Regional convergence: Evidence from a new state-by-state capital stock series. The Review of Economics and Statistics 84, 316–323.

Gollin, Douglas, Parente, Stephen L., Rogerson, Richard, 2004. Farm work, home work, and international productivity differences. Review of Economic Dynamics 7 (4), 827–850.

Gong, Liutang, Xie, Danyang, 2006. Factor mobility and dispersion in marginal products: A case on China. Frontiers of Economics in China 1, 1–13.

Guner, Nezih, Ventura, Gustavo, Xu, Yi, 2008. Macroeconomic implications of size dependent policies. Review of Economic Dynamics 11 (4), 721–744.

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.

Holz, Carsten, in press. Measuring Chinese Productivity Growth, 1952–2007. Manuscript prepared for MIT Press.

Hsieh, Chang-Tai, Klenow, Peter, 2009. Misallocation and manufacturing TFP in China and India. Quarterly Journal of Economics 124 (4), 1403–1448.

Huang, Yasheng, 2008. Capitalism with Chinese Characteristics: Entrepreneurship and the State. Cambridge University Press.

Kamal, Fariha, Lovely, Mary E., 2012. Labor allocation in China: Implicit taxation of the heterogeneous non-state sector. CESifo Economic Studies. http://dx.doi.org/10.1093/cesifo/ifs026.

Ortik, Thomas, 2011. Understanding China's Economic Indicators: Translating the Data into Investment Opportunities. FT Press.

Poncet, Sandra, 2003. Measuring Chinese domestic and international integration. China Economic Review 14 (1), 1–21.

Restuccia, Diego, Rogerson, Richard, 2008. Policy distortions and aggregate productivity with heterogeneous establishments. Review of Economic Dynamics 11 (4), 707–720.

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

Ruhl, Kim J., 2008. The international elasticity puzzle. Mimeo.

Song, Michael Zheng, Storesletten, Kjetil, Zilibotti, Fabrizio, 2011. Growing like China. American Economic Review 101, 202–241.

Vollrath, Dietrich, 2009. How important are dual economy effects for aggregate productivity? Journal of Development Economics 88 (2), 325–334.

Walter, Carl, Howie, Fraser, 2011. Red Capitalism: The Fragile Financial Foundation of China's Extraordinary Rise. Wiley.

World Bank, 2012. China: Structural reforms for a modern, harmonious, and creative high income society. Supporting Report 1 to China 2030.

Young, Alwyn, 2000. The Razor's edge: Distortions and incremental reform in the People's Republic of China. Quarterly Journal of Economics 115 (4), 1091–1135.

Zhang, Xiaobo, Tan, Kong-Yam, 2007. Incremental reform and distortions in China's product and factor markets. World Bank Economic Review 21 (2), 279–299.