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Do research universities boost regional economic development? -- Evidence from China*

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Abstract

This paper studies whether research universities can boost regional economic development through an exogenous shock of a forced relocation of a research university in China. We analyze the development in the treated regions compared with a set of control regions that are created using the synthetic control method and find that research universities can have negative effects on local economic development. We then perform a series of robustness checks. Our main results carry through. By employing a more exogenous shock and more reliable identification strategies, our study provides evidence that research universities do not necessarily promote regional economic development.

Keywords: Research Universities; Regional Economic Development; Synthetic Control Method

JEL-Codes: O15, O18, R11

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1. Introduction

Following the seminal work of Krugman (1991), regional economic development has attracted a great deal of interest among economists. One important topic in this area is on the relationship between universities and regional economies (Drucker and Goldstein, 2007). Policy makers often have a general tendency to believe that universities have a significant role in promoting regional economic development (Miner et al, 2001). However, in recent years, there are some debates over whether the establishment of universities, especially research universities, can contribute to local economic development (Bonander et al., 2016).

Earlier studies generally believe that universities have a positive effect on local economic development (Goldstein et al., 1995). This is because the important role universities play in human capital accumulation, which not only provides basic research, but also can train and attract high-level human capital talents (Moretti, 2004). In addition, some literature points out that universities can promote local economic growth through various complementary mechanisms (Drucker and Goldstein, 2007). For instance, the construction and development of universities can also drive consumption and employment (Moretti, 2010; Moretti and Thulin 2013).

However, some recent empirical studies have produced contrasting results. Feldman (2003) uses Johns Hopkins University as a case study and finds that the existence of Johns Hopkins University does not promote local economic development. Goldstein and Renault (2004) find that universities does not have a significant positive effect on regional economic development, and many subsequent papers have also found similar results (see, among others, Woodward et al., 2006; Drucker, 2016; Bonander et al., 2016).

One common challenge faced by the above empirical studies is the issue of endogeneity. Specifically, there are unobservable features that affect both regional economic development and the establishment of new research universities or a significant increase in research funding.

The main purpose of this paper is to explore the impact of research universities on regional economic development using data from China. To reduce endogeneity, our paper uses a forced university relocation event in China. This event took place in 1977, when a high-level research university in Beijing, the University of Science and Technology of China (USTC)¹, was forced to move from Beijing to Anhui province due to the political movement of the Cultural Revolution (CR). Prior to the move, there was no research university in Anhui, and in fact, even now USTC remains the only high-level research university in Anhui.

To identify the impact of the USTC, we first construct a counterfactual control group when the USTC had not settled in Anhui. We follow Abadie and Gardeazabal (2003), Abadie et al. (2015), Bonander et al (2016) and Gharehgozli (2017) to build a synthetic Anhui by using the synthetic control method (SCM). SCM is arguably the most important innovation in the policy evaluation literature in the last 15 years (Athey and Imbens, 2017). When the data consists of a series of aggregated entities, such as countries or regions, it is often difficult to select a single unaffected unit as a control group for an affected unit. However, SCM is based on the observation that a combination of units in all potential predicted variables, which may approximate the characteristics of affected unit. This allows for a more accurate estimation of treatment effects than the traditional comparative case study approach using a single unit. (Abadie, 2019).

Following Abadie et al. (2015) , we used GDP per capita as a proxy for economic development and compared the changes in GDP per capita in real Anhui and synthetic Anhui before and after the USTC settled in. Our results suggest that, in contrast to synthetic Anhui, the USTC settled in does not contribute to the economic development of the Anhui, but rather imposes significant economic costs. With GDP

¹ USTC is one of the top research universities in China. It is the first university in China to offer "Junior Classes", which admits young people, generally not more than 16 years old, who have not completed their regular secondary school education but who have achieved excellent academic performance to receive university education. and graduate schools, and has been selected for a number of key Chinese government support programs, including the "Double First-Class Project". Double First-Class Project means that in 2017, the Chinese government proposed to build world-class universities and first-class disciplines, of which 36 universities were rated as A, USTC being one of them. According to China's Ministry of Education, the USTC spent 1.5 million RMB per capita on research in 2017, ranking first in the China.

per capita being reduced by about 114 USD per year on average over the 1977-1990 period (approximately 60% of the 1977 baseline level). To evaluate the credibility of our results, we conduct placebo test where the treatment of interest is reassigned in the data to a year other than 1977 or to provinces different from Anhui. Moreover, we conduct robustness checks by changing the weight of synthetic control and reducing the number of units in a synthetic control. Both the placebo test and the robustness checks support our finding that the USTC settled in does not boost Anhui's economic development.

Our paper complements the previous studies by Drucker and Goldstein (2007) and Bonander et al (2016) in two different ways. First, due to an unforeseen political movement in China, USTC, a high-level research university originally located in Beijing, was forced to relocate to Anhui Province. This exogenous shock provides an ideal quasi-experiment to examine the impact of research universities on regional economic development, which helps to reduce endogeneity and increase the credibility of our results on causal inference. Second, some existing studies, such as Bajmócy et al. (2010) and Marozau et al. (2016) point out that the role of universities on regional economic development depends on a region's economic stage. Compared with developed countries, universities are less effective in promoting economic development for developing countries. To the best of our knowledge, most previous empirical studies examine this issue in the developed countries' context, whereas we focus on a developing country. Therefore, our study contributes to the existing literature on the effect of universities on regional economic development.

The rest of the paper is organized as follows. Section 2 presents the background of our research. Section 3 describes the method of synthetic control and data. Section 4 discusses the empirical results. Section 5 conducts robustness checks to test the reliability of the results. Section 6 concludes.

2. Background

Between 1966 and 1976 China went through a 10-year large-scale and unforeseen political upheaval: The Cultural Revolution (CR). The movement first

ignited from Beijing's colleges and universities and was a direct result of the suspension of all college admissions this year from the start (Meng and Zhao, 2016). In February 1969, the three years after the start of the CR, China and the Soviet Union clashed on China's northeast border, the Central Committee of the Communist Party of China (CPC) made a call to prepare for war. In order to avoid being implicated in the colleges and universities and at the same time alleviate the impact of the CR, the document entitled "Circular on the Decentralization of Higher Education Institutions" issued by the CPC Central Committee, a total of 13 colleges and universities were moved out of Beijing. This incident was called the "Beijing Schools Migration" (BSM) in China.

For the 13 colleges and universities which influenced by BSM, the impact of the CR was more than just a change in location. In fact, in response to the "resume classes and rebel" from 1966 to 1976, China's colleges and universities basically stopped their normal admissions and operations. Teachers were unable to conduct normal teaching and research, and the normal college entrance examination enrollment system was also suspended (Chang, 1974). A large number of young students left the universities in the cities and were sent to the poor areas under the influence of the "send-down movement" (Chen et al, 2020). This meant that, in 1966-1976, universities of any type or size were ineffective in the development of the local economy.

The CR officially ended in 1976, and beginning in 1977, China's higher education began to resume enrollment and normal research and teaching. At the same time, 5 of the 13 universities that had been moved out of Beijing returned to Beijing. Of the remaining eight, four of them established "dual-location operation", i.e., they set up campuses in Beijing and the place where they had moved in. This means that the school's resources are distributed between Beijing and the location where they were moved to. These four schools are: China University of Petroleum (UPC), China University of Geosciences (CUG), China University of Mining and Technology (CUMT) and North China Electric Power University (NCEPU). In addition to the common characteristic of "dual-location", another important characteristic is that all

four schools are application-oriented rather than research universities. Finally, the remaining four schools remained in the relocation site. They are: North China University of Water Resources and Electric Power (NCWU), Xi'an University of Technology (XAUT), Wuhan University of Technology (WHUT) and University of Science and Technology of China (USTC).

Considering that the main goal of our study is to examine the impact of research universities on local economic development, we focus on the impact of the USTC on economic development in its relocation area-Anhui. This is because, first, in terms of impact, five of the thirteen schools that have moved out of Beijing have returned to Beijing, and four of them are co-located and are not research universities by nature. XAUT was originally located in Shaanxi, but it absorbed with the Beijing Institute of Mechanics in BSM, WHUT was originally located in Hubei, and it absorbed with the Beijing University of Architecture and Technology in BSM. Therefore, only one research university, USTC, moved completely from Beijing to Anhui. Moreover, before USTC settled in, there was no research university in Anhui. In fact, until today, USTC remains the only high-quality research university in Anhui. USTC is ranked eighth on the 2020 Nature Index Global Top 50 list of research institutions, and it is important that the USTC is able to grow at such a rapid pace with the strong financial support from the Anhui provincial government.

Thus, the move of the USTC from Beijing to Anhui Province provided us with a natural experiment to examine the impact of a research university on local economic development. In fact, the USTC received strong support from the Anhui provincial government after its move to Anhui, but Anhui's economic development has not taken off since then. This supports our view that research universities do not necessarily boost regional economic development.

3. Method and Data

3.1 The synthetic control method

To identify the causal effects of research universities on the regional economic development we use the synthetic control method introduced by Abadie and

Gardeazabal (2003) and then further developed by Abadie et al. (2010, 2015). Suppose that we obtain for $J+1$ units: $j=1, 2, \dots, J+1$. Assume $j=1$ is the treated unit, and “donor pool”, the set of potential comparisons, $j=2$ to $j= J+1$ is a collection of untreated units. The purpose of setting up comparison units is to approximate the counterfactual when the treated did not occur. It is important to restrict the donor pool to units whose outcomes are perceived to be driven by the same structural processes as those representing the case of interest and that are not affected by treated to the outcome variables during the study sampling period. In the application explored later in this article, we investigate the effects of the 1977, USTC settled in Anhui. The case of interest is Anhui in 1977 and the set of potential comparisons is a sample of other provinces in China.

We assume also that our data span T periods and that the first T_0 periods are before the treated. For each unit, j , and time, t , we observe the outcome, $Y_{j,t}$. For each unit, j , we also observe a set of k predictors of the outcome, X_{1j}, \dots, X_{kj} , which are themselves unaffected by the treatment. The $k \times 1$ vectors, $\mathbf{X}_1, \dots, \mathbf{X}_{J+1}$ contain the values of the predictors for units $j=1, \dots, J+1$. The $k \times J$ matrix, $\mathbf{X}_0 = [\mathbf{X}_2, \dots, \mathbf{X}_{J+1}]$, collects the values of the predictors for the J untreated units. We define Y_{jt}^N to be the potential response without treatment, and Y_{jt}^I to be the potential response under treatment. Then, the effect of the treatment in period t (with $t > T_0$) is:

$$\tau_{1t} = Y_{1t}^I - Y_{1t}^N \quad (1)$$

Because $j=1$ is exposed to the treatment after period T_0 , so we have $Y_{1t} = Y_{1t}^I$. But how to estimate Y_{1t}^N reasonably is a great challenge, this is a counterfactual outcome, as the affected all unit was, by definition, exposed to the treatment after $t=T_0$. Notice also that equation (1) allows treatment effects to change over time. This is crucial because treatment effects may not be instantaneous and may accumulate or dissipate as time after the treatment passes (Abadie, 2019).

Typically, comparative case studies tend to reproduce Y_{1t}^N using one untreated unit or a small number of untreated units that had similar characteristics as the treatment unit at the time of the treat. However, when the data consist of a few

aggregate entities, such as regions or countries, it is often difficult to find a single untreated unit that provides an appropriate comparison for the treated units. We wanted through synthetic control to reproduce the Y_{1t}^N by giving different weights $\mathbf{W} = (w_2, \dots, w_{J+1})$ to the samples in the donor pool. Given a set of weights, \mathbf{W} , the synthetic control estimators of Y_{1t}^N and τ_{1t} are, respectively:

$$\hat{Y}_{1t}^N = \sum_{j=2}^{J+1} w_j Y_{jt}, \quad (2)$$

and

$$\hat{\tau}_{1t} = Y_{1t}^I - \hat{Y}_{1t}^N \quad (3)$$

In this way, the choice of weight becomes crucial.² One way to do this is to give equal weight, $w_j = 1/J$, to each of the units in the donor pool in the following estimator for τ_{1t} :

$$\hat{\tau}_{1t} = Y_{1t}^I - \frac{1}{J} \sum_{j=2}^{J+1} Y_{jt} \quad (3)$$

In this case, the synthetic control is the simple average of all the units in the donor pool. Or give weighting to unit according to their population w_j^{pop} in unit:

$$\hat{\tau}_{1t} = Y_{1t}^I - \sum_{j=2}^{J+1} w_j^{pop} Y_{jt} \quad (4)$$

However, Abadie and Gardeazabal (2003) prove that simple averaging is not a good way to construct a counterfactual group corresponding to the treat unit. Given a set of non-negative constants, v_1, \dots, v_k , Abadie and Gardeazabal (2003) and Abadie et al. (2010) propose to choose the synthetic control, $\mathbf{W}^* = (w_2^*, \dots, w_{J+1}^*)'$ that minimizes:

$$\|\mathbf{X}_1 - \mathbf{X}_0 \mathbf{W}\| = (\sum_{h=1}^k v_h (X_{h1} - w_2 X_{h2} - \dots - w_{J+1} X_{hJ+1})^2)^{1/2} \quad (5)$$

subject to the restriction that w_2, \dots, w_{J+1} are non-negative and sum to one. Then, the estimated treatment effect for the treated unit at equation (1) can be rewritten as:

$$\hat{\tau}_{1t} = Y_{1t}^I - \sum_{j=2}^{J+1} w_j^* Y_{jt} \quad (6)$$

² In a recent review of the literature on synthetic control methods, Abadie (2019) discusses the constraints on weight selection. In general, the weights to be non-negative and the sum of the weights to be one. In this paper, we follow this approach.

The positive constants v_1, \dots, v_k in (5) reflect the relative importance of the synthetic control reproducing the values of each of the k predictors for the treated unit, X_{11}, \dots, X_{k1} . That is, each potential choice of $\mathbf{V} = (v_1, \dots, v_k)$ produces a synthetic control, $W(\mathbf{V}) = (w_2(\mathbf{V}), \dots, w_{J+1}(\mathbf{V}))'$, which can be determined by minimizing equation (5). The question then shifts to how to choose \mathbf{V} . According to Abadie and Gardeazabal (2003) and Abadie et al. (2010), the synthetic control $\mathbf{W}(\mathbf{V})$ need minimizes the mean squared prediction error (MSPE) with respect to Y_{1t}^N :

$$\sum_{t \in \mathcal{T}_0} (Y_{1t} - w_2(\mathbf{V})Y_{2t} - \dots - w_{J+1}(\mathbf{V})Y_{J+1t})^2,$$

for some set $\mathcal{T}_0 \subseteq 1, 2, \dots, T_0$ of pre-treatment periods. Further, Abadie et al. (2015) improves on the above with respect to the choice of $\mathbf{W}(\mathbf{V})$, they propose that by selecting the training and validation periods span $t = 1, \dots, t_0$ and $t = t_0 + 1, \dots, T_0$, respectively. In practice, the lengths of the training and validation periods are relatively flexible. For each value \mathbf{V} , let $\tilde{w}_2(\mathbf{V}), \dots, \tilde{w}_{J+1}(\mathbf{V})$ be the synthetic control weights computed with training period data on the predictors. The MSPE with respect to Y_{1t}^N in the validation period is:

$$\sum_{t=t_0+1}^{T_0} (Y_{1t} - \tilde{w}_2(\mathbf{V})Y_{2t} - \dots - \tilde{w}_{J+1}(\mathbf{V})Y_{J+1t})^2, \quad (7)$$

we minimize equation (6), use the resulting \mathbf{V}^* and data on the predictors for the last t_0 periods before in the treatment, $t = T_0 - t_0 + 1, \dots, T_0$, to calculate $\mathbf{W}^* = \mathbf{W}(\mathbf{V}^*)$. In addition, in order to minimize the bias in the SCM estimates, we need to make the post-treatment period smaller than the pre-treatment period (Abadie, 2019).

3.2 Data

We use annual province-level panel data for the period 1960-1990. As described in the background section of Section 2, although USTC moved to Anhui in 1970, however influenced by CR, the USTC did not really operate there until 1977. Therefore, we define the USTC actually settled in Anhui in 1977, giving a pre-treatment period of 17 years. Following Abadie et al. (2015), our sample period ends in 1990 because a roughly decadelong period after the treatment seems like a

reasonable limit on the span of plausible prediction. The synthetic Anhui is constructed as a weighted average of potential control countries in the donor pool.

To construct donor pool, we started with the 30 provincial units in Chinese mainland (excluding Anhui). We first excluded Beijing, Shanghai, Tianjin and Chongqing because these four regions are special administrative regions, province-level municipality, of China, they are geographically the size of cities, but politically they have been given the power of provinces. This makes these four regions not comparable to another province. We also excluded Guangdong, Hainan and Tibet which the data is missing. Heilongjiang, Jilin, and Liaoning are also excluded from our sample because these three provinces are located in the northernmost part of China, while Anhui is in the middle of China, which leads to significant geographic differences between these three provinces and Anhui. In addition, these three provinces are resource-based cities, which are also very different from Anhui in terms of industrial structure. We finally excluded Hebei and Hubei because these provinces were potentially affected by the BSM shocks during the sample period. Geographically, Hebei is surrounded by two province-level municipality- Beijing and Tianjin, which led to the temporary relocation of schools, institutions, teachers, or students to Hebei during the CR. In addition, one of the four "dual-location operation" colleges or universities was also located in Hebei. Similar to this, Hubei not only has a one of the four "dual-location operation" colleges or universities, WHUT, originally located in Hubei, has also absorbed the Beijing University of Architecture and Technology, which moved out of BSM. To ensure that the estimates are as accurate as possible, our donor pool finally includes a sample of 18 provinces in China: Fujian, Gansu, Guangxi, Guizhou, Henan, Hunan, Inner Mongolia, Jiangsu, Jiangxi, Ningxia, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Xinjiang, Yunnan, Zhejiang.³

We provide a list of all variables used in the analysis in the data appendix, along with data sources. The outcome variable, $Y_{j,t}$, is the real per capita GDP in province j

³ It is important to note, however, that when included in the sample of data available above, they also obtain zero weights in the synthetic control for Anhui. Therefore, our main results are identical whether or not we exclude these province (Abadie et al., 2015).

at time t . GDP is Purchasing Power Parity (PPP)-adjusted and measured in 2010 U.S. dollars (USD, hereafter). For the pre-treatment characteristics in X_t and X_0 , we following Abadie and Gardeazabal (2003), Abadie et al. (2015), Bonander et al (2016) and Gharehgozli (2017), rely on a set of economic growth predictors: number of students in higher education, population birth rate, mortality rate, population growth rate, total population, secondary sector value added index, tertiary sector value added index, GDP per capita in 1977, 1965 and 1960 (see the Appendix for details).

4. Results

4.1 Constructing a Synthetic Version of Anhui

Using the techniques described in the methodological section above, we construct a synthetic Anhui with weights chosen so that the resulting synthetic Anhui best reproduces the values of the predictors of per capita GDP in Anhui in the pre-treatment period. We use a cross-validation technique to choose the weights V^* in equation (7). We first divide the pretreatment years into a training period from 1966 to 1971 and a validation period from 1972 to 1977. Next, using predictors measured in the training period, we select the weights V^* such that the resulting synthetic control minimizes the root mean square prediction error (RMSPE) over the validation period.⁴ We estimate the effect of the USTC relocation on per capita GDP in Anhui as the difference in per capita GDP levels between Anhui and its synthetic counterpart in the years following the USTC settled in.

Table 1 shows the weights of each province in the synthetic version of Anhui. The synthetic Anhui is a weighted average of Zhejiang, Henan, Fujian and the Inner Mongolia with weights decreasing in this order. All other province in the donor pool obtain zero weights. As a comparison, Table 1 also reports the weights that regression

⁴ According Abadie et al. (2015), the RMSPE measures lack of fit between the path of the outcome variable for any particular province and its synthetic counterpart. The pre-1977 RMSPE for Anhui is defined as:

$$\text{RMSPE} = \left(\frac{1}{T_0} \sum_{t=1}^{T_0} (Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt})^2 \right)^{1/2}.$$

The RMSPE can be analogously defined for other province or time periods.

analysis employs implicitly when applied to the same data.⁵ By construction, both sets of weights sum to one. The two sets of weights show some similarities. For example, Fujian, Inner Mongolia and Henan all received high weights in both approaches. However, the weights are different. For example, the weights assigned to Zhejiang are quite different in the two applications. Moreover, regression assigns negative weights to six provinces of the 19 control units in the donor pool. As discussed by Abadie et al. (2020), negative weights indicate that regression relies on extrapolation.

Table 2 compares before USTC settled in characteristics of Anhui to those of the synthetic Anhui, and also to those of a population-weighted average of the other 18 provinces in the donor pool. Overall, the results in Table 2 suggest that the synthetic Anhui provides a much better comparison for Anhui than the average of our sample of other provinces. The synthetic Anhui is quite similar to the actual Anhui in terms of pre-1977 number of students in higher education, population birth rate, mortality rate, population growth rate, total population, secondary sector value added index, tertiary sector value added index, and GDP per capita in 1977, 1965, 1960. Figure 1 shows that before the USTC settled in, Anhui and the other provinces average experienced different paths in per capita GDP. However, in the next section, we will show that a synthetic control can accurately reproduce the pre-1977 per capita GDP path for Anhui.

4.2 The Effect of the 1977 USTC settled in Anhui

Figure 2 displays the per capita GDP trajectory of Anhui and its synthetic counterpart for the 1960-1990 period. The synthetic Anhui almost exactly reproduces the per capita GDP for Anhui during the entire before USTC settled in period. This close fit for the pretreatment per capita GDP and the close fit that we obtain for the

⁵ As in footnote 3, we declare that the weights to be non-negative and the sum of the weights to be one. However, a regression-based approach also uses a linear combination of the untreated units with coefficients that sum to one as a comparison, this approach does not restrict the coefficients of the linear combination that define the comparison unit to be between zero and one, therefore allowing extrapolation outside the support of the data. Based on Abadie et al. (2015), if unnecessary in the context of our example, we just need show that there exists a synthetic control that closely fits the values of the characteristics of the units and that does not extrapolate outside of the support of the data.

GDP predictors in Table 2 demonstrate that there exists a combination of other provinces that reproduces the economic attributes of Anhui before the USTC settled in. That is, it is possible to closely reproduce economic characteristics of Anhui before the 1977 USTC settled in without extrapolating outside of the support of the data for the donor pool.

Our estimate of the effect of the USTC settled in Anhui on per capita GDP in Anhui is given by the difference between the actual Anhui and its synthetic version, visualized in Figure 3. In a significant departure from most previous studies, we find that rather than helping Anhui's economic development, USTC's relocation has resulted in quite significant economic costs. Compared to synthetic Anhui, real Anhui's GDP per capita has been significantly lower since 1977. There is a significant difference between the two lines. Our results are in line with the recent studies by Vu et al. (2012) and Bonander et al. (2016) that research university construction does not necessarily lead to local economic development.

The gap between the two series has a tendency to widen from the beginning of the treatment period to near the end of the sample period. Thus, our results indicate that the relocation of USTC has a significant negative impact on the economic development of Anhui. We find that over the entire 1977–1990 period, per capita GDP was reduced by about 114 USD per year on average, which amounts to approximately 60% of the 1977 baseline level. In 1990, per capita GDP in synthetic Anhui is estimated to be about 44% higher than in the actual Anhui.

One valid concern in the context of this study is the potential existence of spillover effects. In particular, it is possible that the USTC settled in Anhui has effects on per capita GDP in other provinces. Abadie et al. (2015) consider that the limited number of units in the synthetic control allows the evaluation of the existence and direction of potential biases created by spillover effects. For example, if the USTC settled in has negative spillover effects on the per capita GDP of the provinces included in the synthetic control, then the synthetic control could provide an underestimate of the counterfactual per capita GDP trajectory for Anhui in the absence of the USTC settled in and, therefore, an underestimate of the negative effect

of the reunification on per capita GDP in Anhui. On the other hand, if the USTC settled in has positive effects in the economies included in the synthetic control, this could exacerbate the negative effect of the synthetic control estimates. Notice also that spillover effects on provinces that are not included in the synthetic control do not affect the synthetic control estimates.

4.3 Placebo Studies

In this section, we conduct placebo studies where the treatment of interest is reassigned in the data to a year other than 1977 or to province different from Anhui. We first compare the effect of USTC settled in Anhui to a placebo effect obtained after reassigning the USTC settled in Anhui in our data to a period before the USTC settled in actually took place, large placebo estimate would undermine our confidence that the results in Figure 2 are indeed indicative of the economic cost of USTC settled in and not merely driven by lack of predictive power (Abadie et al., 2015).

To conduct this placebo study, we assumed that the USTC settled in Anhui in the year 1970, the year 1970 was chosen for two reasons: first, as explained in the background section, it is true that USTC physically moved to Anhui in 1970, but due to the political movement of the CR, teachers and students were forced to participate in the "revolution". All colleges and universities stopped normally enrolling students and carrying out normal research activities until the end of the CR in 1976. Second, since our sample started in 1960, we chose 10 years as the pre-processing length in order to ensure that the synthetic control period was long enough. We use the same out-of-sample validation technique to compute the synthetic control, and we lag the predictors variables accordingly for the training and validation period. Figure 4 displays the results of this "in-time placebo" study. The synthetic Anhui almost exactly reproduces the evolution of per capita GDP in the actual Anhui for the 1960-1970 period. Most importantly, the per capita GDP trajectories of Anhui and its synthetic counterpart do not diverge considerably during the 1970-1977 period. That is, in contrast to the actual USTC settled in, our 1970 placebo USTC settled in has no perceivable effect. This suggests that the gap estimated in Figure 2 reflects the impact

of the USTC settled in not a potential lack of predictive power of the synthetic control.

An alternative way to conduct placebo studies is to reassign the treatment in the data to a comparison unit. In this way, we can obtain synthetic control estimates for provinces that did not experience the event of interest. Applying this idea to each province in the donor pool allows us to compare the estimated effect of the USTC settled in Anhui to the distribution of placebo effects obtained for other provinces. We will deem the effect of the USTC settled in Anhui is significant if the estimated effect for Anhui is unusually large relative to the distribution of placebo effects.

Figure 5 reports the ratios between the post-1977 RMSPE and the pre-1977 RMSPE for Anhui and for all the countries in the donor pool. The RMSPE measures the magnitude of the gap in the outcome variable of interest between each province and its synthetic counterpart. If the synthetic control does not closely reproduce the relevant results before the intervention and the RMSPE is larger after the intervention, the effect of the intervention is not large. That is, a large post-intervention RMSPE is not indicative of a large effect of the intervention if the post-1977 RMSPE is also large. For each province, we divide the post-1977 RMSPE by its pre-1977 RMSPE. In Figure 5, Anhui has almost the highest RMSPE rate, and for Anhui, the post-1977 gap is about 17 times larger than the pre1977 gap. If one were to pick a province at random from the sample, the odds of getting a rate as high as this one would be $2/19 \approx 0.105$.

5. Robustness Checks

5.1 Sensitivity analysis of changing weights

To evaluate the credibility of our results, we run a robustness check to test the sensitivity of our main results to changes in the country weights, V^* . Recall from Table 1 that synthetic Anhui is estimated as a weighted average of Zhejiang, Henan, Fujian and the Inner Mongolia, with weights decreasing in this order. Here we iteratively re-estimate the baseline model to construct a synthetic Anhui omitting in each iteration one of the provinces that received a positive weight in Table 1.

By excluding provinces that received a positive weight, we sacrifice some goodness of fit, but this sensitivity check allows us to evaluate to what extent our results are driven by any particular control province. Figure 6 displays the results and reproduces Figure 2 (solid and dashed black lines) while also incorporating the leave-one-out estimates (gray lines). This figure shows that the results of the previous analysis are fairly robust to the exclusion of any particular province from our sample of comparison provinces.

5.2 Reducing the Number of Units in a Synthetic Control

The synthetic Anhui in Figure 2 is a weighted average of four provinces: Zhejiang, Henan, Fujian and the Inner Mongolia. However, comparative researchers usually select only a very small number of cases, with the aim of carefully characterizing and analyzing the characteristics and results of each of these cases. In many cases, therefore, comparative researchers may prefer sparse synthetic controls, that is, involving a small number of comparison units. However, reducing the number of units in a synthetic control may affect the extent to which the synthetic control is able to fit the characteristics of the unit of interest. In this section, we will show whether, at the expense of some degree of fit, the regressions are still robust when the number of synthetic control units in Anhui is chosen to be sparse.

In Table 3, we show construct synthetic controls for Anhui, allowing combinations of four (baseline synthetic control in part 4.1), three, two, and a single control province, respectively. For this example, the provinces contributing to the sparse versions of the synthetic control for Anhui are subsets of the set of four provinces contributing to the synthetic control in the baseline specification. Zhejiang retains the largest weight in all instances, whereas the Henan, Fujian, Inner Mongolia are second, third, and fourth in terms of their synthetic control weights.

Table 4 compares predictors of Anhui, synthetic Anhui, the sparse versions of synthetic Anhui, and the other provinces sample. This table documents the sacrifice in terms of goodness of fit resulting from a reduction in the number of provinces, allowed to contribute to the synthetic control.

Relative to the baseline synthetic control with four provinces, the decline in goodness of fit is moderate for three and two provinces. The “matching” case of one unit, where the synthetic Anhui is Zhejiang, produces a much worse goodness of fit relative to control provinces over one, with substantial discrepancies in each predict variables. However, even the matching case, one unit, represents a large improvement in terms of goodness of fit relative to the comparison unit consisting of the population weighted average of the other provinces.

Figure 7 shows the per capita GDP path for Anhui and the sparse synthetic controls with four to one unit. With the exception of the matching case, one unit, the sparse synthetic controls in Figure 7 produce results that are very similar to the baseline result. However, using a single province, Zhejiang, as a comparison provides a much poorer fit to the pre-1977 per capita GDP path for Anhui. However, although the use of a single unit does not provide the potential benefits of a comparison case, the overall results of our analysis are robust in demonstrating that building a research university does not necessarily boost regional economic development.

6. Concluding Discussion

Using the exogenous impact of a forced university relocation that occurred during the Cultural Revolution in China, we study the impact of the relocation of a research university, the University of Science and Technology of China (USTC), from Beijing to Anhui Province, on Anhui's economic development. By employing the synthetic control method, we construct a synthetic Anhui as the potential economic development without the relocation of the USTC. We find that the USTC has had a significant negative impact on the economic development of Anhui. Specifically, from the whole period, compared to Synthetic Anhui, real Anhui's per capita GDP was reduced by about 114 USD per year on average over the 1977-1990 period (approximately 60% of the 1977 baseline level). At the end of our analysis period, the year of 1990, per capita GDP in synthetic Anhui is estimated to be about 44% higher than in the actual Anhui.

Our study provides further empirical evidence for the existing literature that casts doubt on the effectiveness of universities in regional development. In contrast to previous empirical studies that found some positive effect of research universities on regional economic development or only a weak effect, our findings distinctly point out that research universities impose significant economic costs on regional economic development. How do we understand this result?

First, following the existing literature, we argue that the impact of research universities on regional economic development may need to be examined over a longer period of time and in a wider spatial context. In time, as the research of Bajmócy et al. (2010) points out, universities have different impacts on economies at different economic stages, with human capital often playing an important role in long-term economic development (Romer, 1986). In terms of spatial, as argued by Drucker (2015), interregional migration may be a reason for small or no regional economic effects of universities, making the benefits of universities not region specific.

Second, we believe that brain drain may be a contributing factor. Many findings in development economics have pointed out that the brain drain has significant side effects on the economic growth of the outgoing countries (Bhagwati and Hamada, 1974). In fact, Anhui province is not a developed region in China. Compared with Beijing, Shanghai, Guangzhou and other super cities, Anhui lacks attractiveness for talents. According to the “2019 Employment Quality Report” released by the USTC, only 22% of graduates remain employed in Anhui. In contrast to the Anhui government's strong support for USTC, Anhui is not attractive enough to retain the talent trained by USTC. This may result in inputs being much greater than outputs, with the overall picture showing that USTC has significant economic costs for Anhui.

In summary, our study shows that research universities do not necessarily boost regional economic development. This may imply, firstly, that it is difficult for developing countries or regions to achieve economic development in the short term through the development of higher education. Secondly, the attractiveness of the region to human resources should be improved. Policies on higher education may

need to take a longer-term view, and be complemented by other complementary policies to attract talent.

Table 1 Synthetic and Regression Weights for Anhui

Province	Synthetic Control Weight	Regression Weight	Province	Synthetic Control Weight	Regression Weight
Fujian	0.15	0.49	Ningxia	0	0.23
Gansu	0	0.03	Qinghai	0	-0.18
Guangxi	0	-0.02	Shaanxi	0	0.1
Guizhou	0	-0.42	Shandong	0	0.01
Henan	0.32	0.3	Shanxi	0	-0.01
Hunan	0	0.19	Sichuan	0	0.48
Inner Mongolia	0.07	0.3	Xinjiang	0	0.1
Jiangsu	0	-0.4	Yunnan	0	0.05
Jiangxi	0	-0.34	Zhejiang	0.46	0.09

Note: The synthetic weight is the province weight assigned by the synthetic control method. The regression weight is the weight assigned by linear regression. See text for details.

Table 2 Economic Growth Predictor Means before USTC settled in

	Anhui	Synthetic Anhui	Other Provinces
Number of students in higher education	1.443	1.028	1.196
Population birth rate	27.282	24.389	28.123
Mortality rate	5.823	6.597	7.665
Population growth rate	6.933	10.513	14.157
Total population	4433.833	4227.718	3245.729
Secondary sector value added index	112.017	109.564	111.265
Tertiary sector value added index	108.067	108.942	109.785
GDP per capita in 1977	190.843	198.563	216.309
GDP per capita in 1965	126.118	132.314	147.002
GDP per capita in 1960	160.9	154.887	171.593

Note: Number of students in higher education, population birth rate, mortality rate, population growth rate, total population, secondary sector value added index, and tertiary sector value added index are averaged for the 1960-1977 period. The last column reports a population-weighted average for the 18 provinces in the donor pool.

Table 3 Synthetic Weights from Combinations of Control Provinces

Synthetic Combination	Provinces and <i>W</i>-Weights			
Four control Provinces	Zhejiang	Henan	Fujian	Inner Mongolia
	0.46	0.31	0.15	0.07
Three control Provinces	Zhejiang	Henan	Fujian	
	0.55	0.27	0.18	
Two control Provinces	Zhejiang	Henan		
	0.71	0.29		
One control Provinces	Zhejiang			
	1			

Note: Province and *W*-weights for synthetic control are constructed from the best-fitting combination of four, three, and two provinces, as well as one province. See text for details.

Table 4 Economic Growth Predictor Means before the USTC settled in for Combinations of Control Provinces

	Anhui	Synthetic Anhui Number of province in synthetic control				Other Provinces
		4	3	2	1	
Number of students in higher education	1.4	1	1	1	0.8	1.2
Population birth rate	27.3	24.4	24.2	22.6	21	28.1
Mortality rate	5.8	6.6	6.6	6.5	6.2	7.7
Population growth rate	6.9	10.5	10.4	9.4	8.6	14.2
Total population	4433.8	4227.5	4176.4	4484	3584.8	3245.7
Secondary sector value added index	112	109.6	108.6	107	104.5	111.3
Tertiary sector value added index	108.1	108.9	108.9	109.5	110.2	109.8
GDP per capita in 1977	190.8	198.6	198.9	205.2	219.9	216.3
GDP per capita in 1965	126.1	132.3	129.8	132.1	147.7	147
GDP per capita in 1960	160.9	154.8	148.4	146	157.7	171.6

Note: Number of students in higher education, population birth rate, mortality rate, population growth rate, total population, secondary sector value added index, and tertiary sector value added index are averaged for the 1960-1977 period.

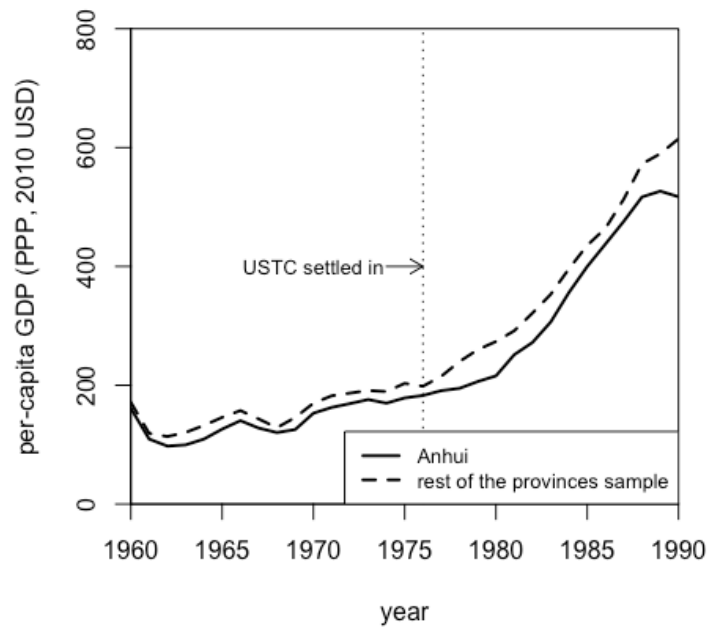


Figure 1 Trends in per Capita GDP : Anhui versus Rest of the provinces sample

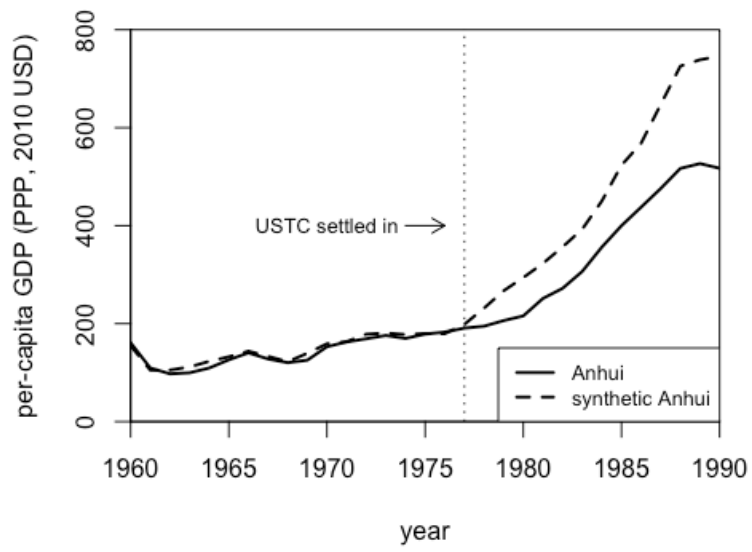


Figure 2 Trends in per Capita GDP : Anhui versus Synthetic Anhui

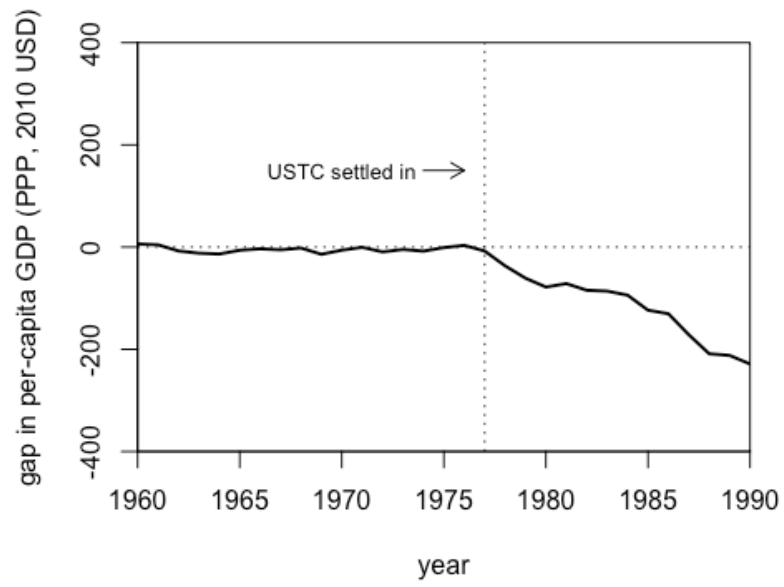


Figure 3 Per Capita GDP Gap between Anhui and Synthetic Anhui

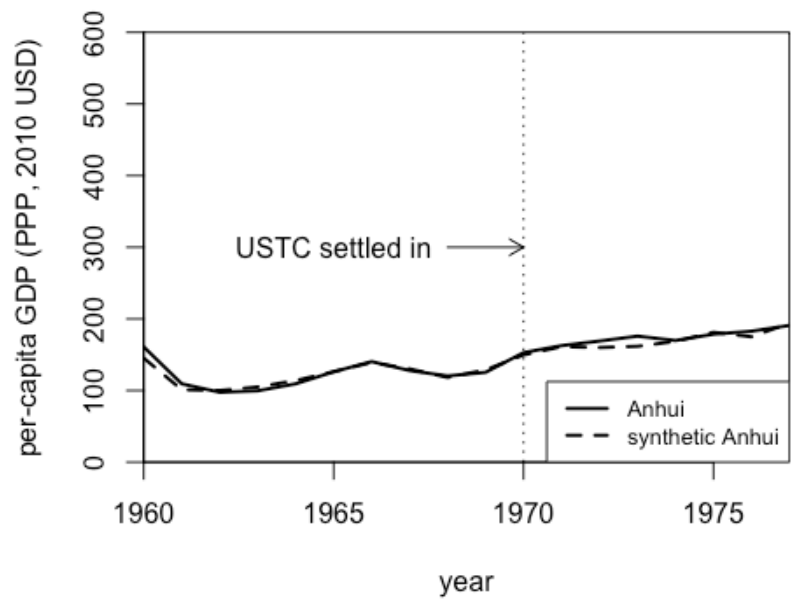
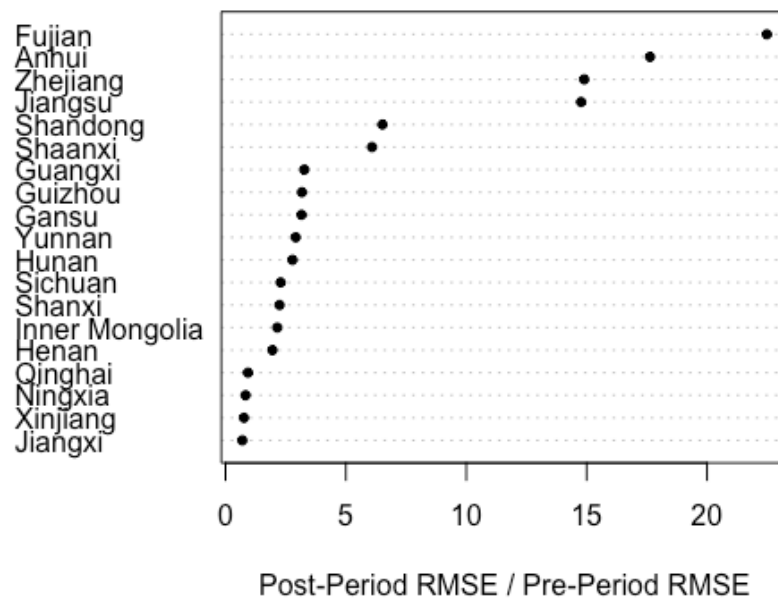


Figure 4 Placebo USTC settled in 1970-Trends in per Capita GDP: Anhui versus Synthetic Anhui



**Figure 5 Ratio of Post-USTC settled in RMSPE to USTC settled in RMSPE:
Anhui and Control Provinces**

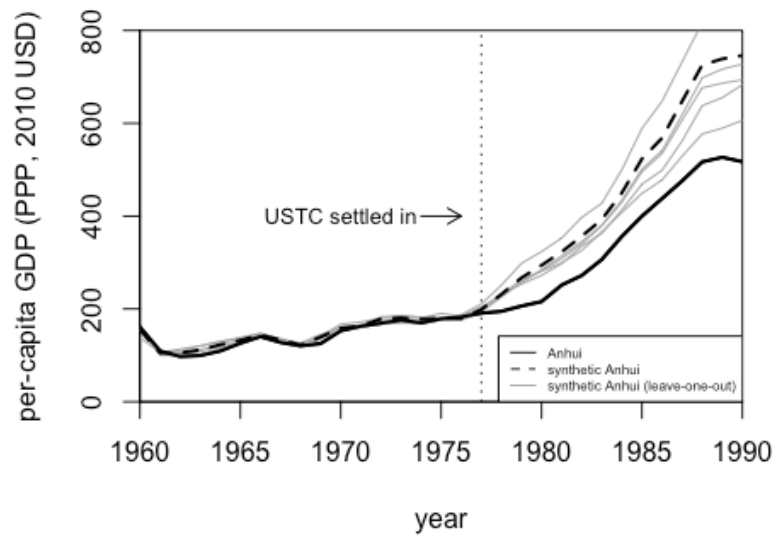


Figure 6 Leave-One-Out Distribution of the Synthetic Control for Anhui

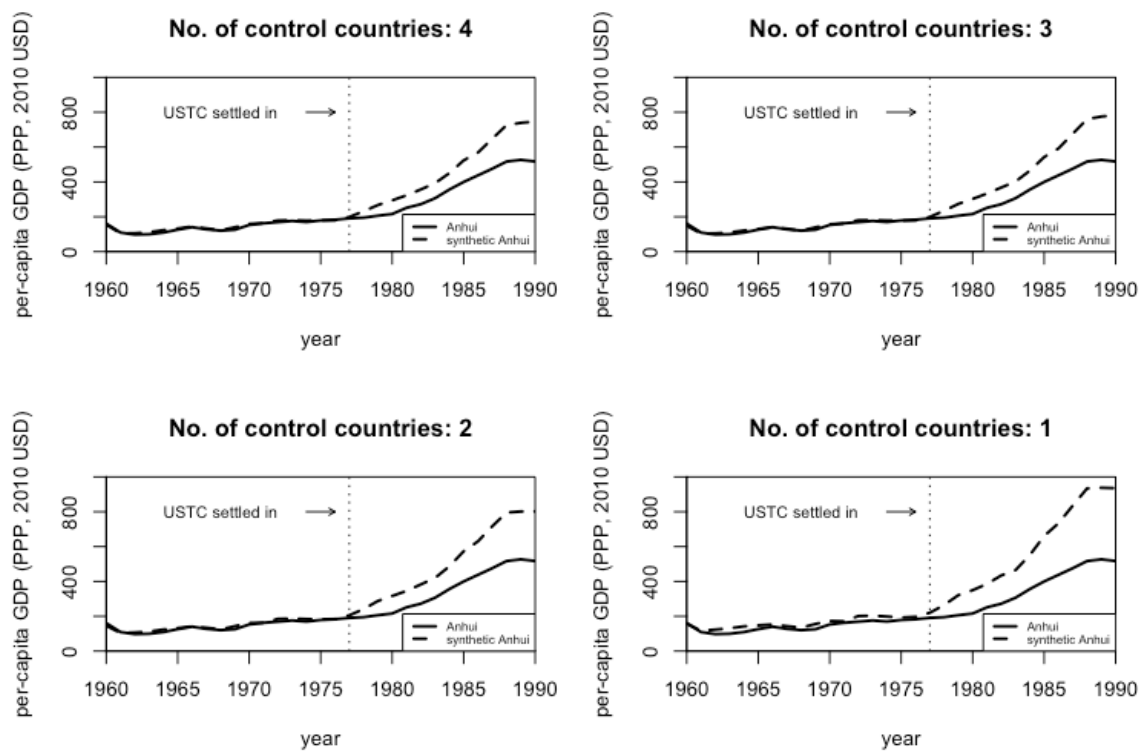


Figure 7 Per Capita GDP Gaps between Anhui and Sparse Synthetic Controls

Appendix

The data sources employed for the application are as follows:

1. GDP per capita (PPP,2010USD). Source: World Bank Open Data and National Bureau of Statistics of the People's Republic of China. Through the World Bank Open Data, we obtained GDP per capita (PPP,2010USD) in 1960-1990 of China. Through the National Bureau of Statistics of the People's Republic of China, we obtained real GDP per capita (CNY) of China and each province real GDP per capita (CNY) of China in 1960-1990. After the conversion, we calculated each province GDP per capita (PPP,2010USD) of China in 1960-1990.
2. Number of students in higher education. Measuring the number of students in higher education in each province. Measuring in tens of thousands. Source: National Bureau of Statistics of the People's Republic of China.
3. Population birth rate. The birth Population birth rate is the ratio of the number of births in a given area over a one year to the average number of births over the same period, expressed in parts per thousand. The number of births refers to live births, i.e., when the fetus is separated from the mother's body (regardless of the number of months of gestation) and has experienced respiration or other vital signs. Source: National Bureau of Statistics of the People's Republic of China.
4. Mortality rate. Mortality rate is the ratio of the number of deaths in a given area over a one year to the average number of deaths over the same period, expressed in parts per thousand. Source: National Bureau of Statistics of the People's Republic of China.
5. Population growth rate. Population growth rate is the ratio of the natural increase in population (births minus deaths) over a one year to the average number of persons over the period, expressed in parts per thousand. Source: National Bureau of Statistics of the People's Republic of China.
6. Total population. Total population is the total number of living individuals within a given area as of December 31, 24 hours in each year. Measuring in

tens of thousands. Source: National Bureau of Statistics of the People's Republic of China.

7. Secondary sector value added index. Secondary sector value added index refers to the value added of the secondary industry (the final result of the production activities of all resident units in a country or region in a certain period of time, calculated at market prices). The secondary sector is defined as mining (excluding auxiliary mining activities), manufacturing (excluding repair of metal products, machinery and equipment), production and supply of electricity, heat, gas and water, and construction). Relative to the trend and magnitude of change, this indicator is an index calculated on the basis of the previous year. Calculated at constant prices. Source: National Bureau of Statistics of the People's Republic of China.
8. Tertiary sector value added index. Tertiary sector value added index refers to the final results of the production activities of all resident units in a country or region in the tertiary industry at market prices within a certain period of time. Tertiary industry refers to the relative number of the trend and degree of changes in industries other than primary (agriculture, forestry, animal husbandry, fishery, excluding agriculture, forestry, animal husbandry, fishery services) and secondary industries, and the index is calculated on the basis of the previous year. It is calculated at constant prices. Source: National Bureau of Statistics of the People's Republic of China.
9. GDP per capita in 1977, 1965 and 1960 (PPP,2010USD). GDP per capita of each province in 1977, 1965 and 1960.

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