Front. Educ. China 2013, 8(2): 266–302
DOI 10.3868/s110-002-013-0018-1

RESEARCH ARTICLE

Frank BICKENBACH, Wan-Hsin LIU

Regional Inequality of Higher Education in China and the Role of Unequal Economic Development

Abstract Over the past decade the scale of higher education in China has expanded substantially. Regional development policies have attempted to make use of scale expansion as a tool to reduce inequality of higher education among regions with different development levels by providing poor regions with preferential treatment and support. This paper analyzes a provincial dataset (1997–2008), aiming to provide comprehensive quantitative evidence for the development of inequality of opportunity in higher education across provinces in China over the period of scale expansion. Results show that, for higher education, regional inequality relative to provincial population size clearly decreased over the research period. Accompanying the reduction in overall inequality across provinces, inequality between poor and rich regions actually increased over the same period. However, the increase was realized in favor of the poor region. The empirical results are consistent with the policy orientation of reforming the higher education system and of promoting regional development in China over the past decade.

Keywords higher education, regional inequality, China, Theil index

Introduction

China's strong economic growth over the past decades has attracted a great deal of attention worldwide. The open door policy since the late 1970s has induced an inflow of large Foreign Direct Investments (FDI) especially in labor-intensive industries aiming to profit from China's large resources in terms of its low-cost labor force. As a result, labor-intensive industries have developed rapidly. These industries are now well integrated into global production networks and

Frank BICKENBACH
Kiel Institute for the World Economy, 24105 Kiel, Germany

Wan-Hsin LIU (✉)
Kiel Institute for the World Economy, 24105 Kiel, Germany
E-mail: wan-hsin.liu@ifw-kiel.de

responsible for the low value-added part of the production activities of the global value chain in particular. Against the background of intensified market competition and a rising challenge from increasing labor costs, the Chinese government has gradually revised its economic policy towards promoting more innovation and upgrading. A highly qualified labor force is considered crucial for making progress in innovation and upgrading.

To improve the average education level of the Chinese labor force and to increase the provision of highly qualified workers for companies in China, the Chinese government has already made some progress in reforming its higher education system. Above all, over the past decade the scale of higher education in China has expanded substantially. Local governments and universities have been granted more autonomy in managing university-related affairs. Local governments have been encouraged to take over the operation of some universities that had been managed centrally before and to fund new universities, taking into account the local needs for promoting societal and economic development. The central government has restricted itself to focusing on a much smaller number of universities in China.[1] Though students from provinces other than those where the centrally governed universities are located also have opportunities through the national university entrance exam to study at these universities, the home-biased pre-determined new student quotas of such universities restrict cross-provincial mobility.[2] Over the reform process the local and regional features of the higher education system in China have become more pronounced (Central Committee of the Communist Party of China, 1985, 1993, 1999; National Education Committee, 1995; Standing Committee of the National People's Congress, 1998; State Council of the People's Republic of China, 1994).

---

[1] In 1998 about one third of all universities were centrally governed. By contrast, in 2008, only about 5% of all universities were governed by central ministries and agencies. (Ministry of Education of the People's Republic of China, 1999, 中国教育经费统计年鉴 [China Educational Finance Statistical Yearbook]. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press]; National Bureau of Statistics of China, 2009, 中国人口和就业统计年鉴 [China Population and Employment Statistics Yearbook]. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press]).

[2] Though the entrance exam is called the "national university entrance exam," different provinces may use different exam sheets for the same subject. Moreover, students taking the exam compete directly with other students from the same province but not with those from other provinces. The distribution of students to universities is based on the students' score-based positions among all exam participants from the same province and their preference for majors and universities. However, the possibility of students getting access to universities, especially to non-local ones, strongly depends, in addition, on the pre-determined province-specific new student quotas of the individual universities (e.g., Chen, 2004; He, 2007).

The scale expansion in higher education has transformed the system in China from one emphasizing elite education to one promoting mass higher education, aiming to enhance the average educational level and qualifications of the Chinese labor force. The policy decision for scale expansion in higher education (Central Committee of the Communist Party of China, 1999) concerned all 31 provinces in the Chinese mainland[3]. However, due to regional economic considerations, the central government has stressed expansion of higher education in economically backward provinces. Over the last decade, regional economic policy determined by the central government has increasingly gained importance. Its focus is on promoting economic development and/or industrial structural change in the provinces of the Western, Central, and North-Eastern regions of China. Compared to the provinces of the Coastal or Eastern region, economic development in these three regions has clearly lagged behind.[4] Taking into account the idiosyncratic characteristics of the three regions, different regional policy decisions have been announced by the central government. Reforming and/or expanding the local and regional higher education systems has been emphasised with different weights in these region-specific policy decisions. According to the corresponding policy decisions, the expansion and further improvement of the higher education system in particularly poor provinces (Western region) should obtain preferential treatment and support from the central government. The aim is to support the convergence of the shares of the population with higher education in these provinces with the corresponding national average share (General Office of the State Council of the People's Republic of China, 2001, 2002; Office of Western Development of the State Council of the People's Republic of China, 2002; State Council of the People's Republic of China, 2000, 2004). For the North-Eastern and Central regions, which are more developed than the Western region, the regional economic policy plans also mentioned the importance of higher education. The promotion of higher education and in particular the quantitative increase in higher education opportunities was less strongly emphasised for these regions, however, and no preferential treatment, comparable to that for the Western region, was explicitly provided (Central Committee of the Communist Party of

[3] More precisely, the provincial level division consists of 22 provinces, five autonomous regions and four municipalities. For simplicity this article refers to all of these units as provinces.

[4] The Western region comprises 12 provinces and municipality (Chongqing, Gansu, Guangxi, Guizhou, Inner Mongolia, Ningxia, Qinghai, Shaanxi, Sichuan, Tibet, Xinjiang, Yunnan), the Central region six provinces (Anhui, Henan, Hubei, Hunan, Jiangxi, Shanxi) and the North-Eastern region three provinces (Heilongjiang, Jilin, Liaoning). The Coastal (Eastern) region comprises 10 provinces and municipalityes (Beijing, Fujian, Guangdong, Hainan, Hebei, Jiangsu, Shandong, Shanghai, Tianjin, Zhejiang).

China, 2003, 2006; General Office of the Central Committee of the Communist Party of China, 2004; National Development and Reform Commission & Office of the Leading Group for Revitalizing Northeast China and Other Old Industrial Bases of the State Council, 2007).

Have these policy objectives and related decisions actually led to a more equal distribution of higher education opportunities among regions and provinces in China and have poor provinces actually benefited the most from the expansion of the higher education system? Or have the policy changes that give local governments more autonomy in managing university affairs actually led to a deterioration in the distribution of higher education opportunities due to local governments' different resource endowments for supporting higher education expansion (as suspected by Dong & Shen, 2000, for example)? Previous literature mostly argued that the specific historical developing background and policies in China inevitably led to a strongly unequal spatial distribution of higher education opportunities in the past (e.g., Zhu & Bei, 2000; Dong & Shen, 2000). Jia (2009) concludes that (central) government policies have played a much more important role in this context than other potential local determinants such as economic development and population size. More specifically, Qiao (2007) argues that regional policies encouraging economic development in the Western region with its high share of ethnic minority population seemed to support the expansion of the higher education system in this region, thereby giving it an advantage over other poorly developed regions. His research, however, focuses on one-year data and on a small number of universities (centrally-governed) only.

The regional distribution of higher education in China has been formally analyzed by several studies, using various research methods and datasets. A common feature of most of these studies is that their research period is generally quite short and they do not consider other provincial characteristics, such as strong differences in the size of provinces, in their analyses in a comprehensive and systematic way. Xue and Xue (2002) use one-year city-level data to specify the geographic city center in China and the center of the mass of population, economic activity and higher education in China, respectively. They find that the four centers specified did not correspond to each other, suggesting different distributional patterns in all four aspects considered, although the four centers were not located far from each other. Zhang and Xing (2008) extend the number of dimensions of higher education analyzed and consider 12 different aspects of higher education, including the number of universities, the number of graduates, the financial budget for education, and educational expenditures. Through factor analyses they classify the 12 aspects considered into two groups representing the scale and quality of higher education, respectively. They find that for a majority of provinces the scale of higher education corresponds positively to the quality of higher education, suggesting that provinces equipped with more university places also exhibited a better educational quality of universities. Such a positive relationship between the scale and quality of higher education may be partially explained by differences in local governments' financial capabilities. Generally, richer governments will find it easier to finance both a higher number and a better quality of universities. This view is in line with the finding from Zhao, Liu, Liang, and Miao (2007) that the number of university students is highly positively correlated with provincial gross domestic product (GDP).

Changes over time in the interregional inequality of the higher education opportunities have been analyzed more directly by Shen (2007a, 2007b). Calculating various inequality measures, including extreme values, standard deviations, the coefficient of variation, and the Gini index for distribution of the number of universities for some selected years from 1949 to 2003, Shen (2007a) finds some support for a reduction in the interregional inequality of the number of universities. His analysis does not take any provincial characteristics, such as their grossly different population sizes, into consideration, however. Only for one year (the year 2002) he calculates the interregional inequality (measured by the coefficient of variation) of the distribution of the number of universities or students relative to the population size. The restriction of this part of the analysis to just one year does not allow him to assess the evolution over time of these population-relative inequality measures, however. Shen (2007b) advances this issue by calculating both the coefficient of variation and the Gini index based on the number of new students relative to the 18-year old population for 1989, 1993, 1997, and 2000. He does not find a clear trend in the development of the regional inequality of the distribution of new students relative to the 18-year old population, however. In a related study, Liu, Zhao, and Sun (2009) calculate various inequality measures, namely the coefficient of variation, the Gini index and the Theil index, for the number of students relative to population sizes for the years 2004 to 2006. In contrast to Shen (2007b) they find that the inequality in the relative number of students has been following a clearly decreasing trend between 2004 and 2006. Liu et al. (2009) also examine the interregional inequality in the number of students relative to the provinces' GDP. Contrary to the case of the population reference, they do not find a clear trend in the evolution of the interregional inequality of higher education opportunities when using GDP as the reference.

These differential, in part seemingly contradictory, findings of the relevant literature suggest that a more comprehensive and systematic analysis of the issue will be necessary to adequately describe and assess the evolution of regional inequality in higher education opportunities during the recent phase of higher education expansion in China. Such an analysis needs to cover more observations over a longer time horizon and should consider different relevant regional characteristics as references. A first important step in this direction is undertaken by Liu (2007). He analyzes the evolution of the inequality of the number of university students relative to the provinces' young population between 1998 and 2006. Using the Gini index and Theil index to measure inequality, he finds a somewhat decreasing trend of inequality over time but with an apparent rebounding of inequality in 2006. He, thus, suggests that further research on the inequality issue in higher education opportunities in China is crucial for a better understanding of the evolution of the inequality in higher education opportunities. Research on the issue should be extended along several dimensions. It could extend the period of analysis beyond 2006 in order to see whether there has really been a rebound of inequality at that time. It could employ alternative datasets on the provinces' levels of higher education (opportunities) to avoid potential measurement biases (see Liu, 2007, p. 145, for a discussion of a potential measurement bias in his data on the number of newly enrolled students from the different regions). In addition, it could use alternative regional characteristics as references. Apart from checking the robustness of results this would also allow the consideration of not only the demand for higher education opportunities by the young population but also the demand for a highly qualified labour-force by the manufacturing and service sectors as reference. Finally, it could complement the analysis of inequality across provinces by an analysis of inequality between and within meaningfully defined groups of provinces.

The current paper attempts to deepen the investigation into the unequal distribution of higher education opportunities in China along all of these dimensions. It aims to provide systematic and robust statistical evidence on the development of the inequality in higher education opportunities across provinces and regionally and economically defined groups of provinces over the period of higher education expansion. In order to do so, it employs a provincial panel dataset for the period from 1997 to 2008 to calculate a series of generalized Theil inequality indices with different regional weights and references, which allow us to highlight various aspects of the issue of the evolution of the inequality in higher education opportunities across (groups of) Chinese provinces.

The remainder of the paper is organized as follows. Section 2 (The Higher Education System and Regional Economic Development: An Overview) briefly describes some key quantitative features of the (development of) the higher education system in China and of inter-regional differences in economic development. Section 3 (Data and Method) introduces our dataset and defines and briefly discusses our preferred inequality measure, the generalized Theil index. Section 4 (Regional Inequality of Higher Education Opportunities: Empirical Results) describes our results on the evolution of the inequality in the distribution of higher education opportunities across provinces (and groups of provinces) taking provincial heterogeneity in size and structural development into account. Section 5 (Summary and Discussion) summarizes the empirical results and discusses them in light of the Chinese government's regional economic policy priorities. Definitions and selected results for alternative inequality measures are deferred to two Appendices.

The Higher Education System and Regional Economic Development: An Overview

Prior to the policies that decided on a large scale expansion of higher education opportunities in 1999, the higher education system in China was designed to support higher education of a rather small elite. There had already been some increase over time in the number of universities and the number of students from 1978 (the year of the revival of the national university entrance exam) to 1998. That increase was rather modest, however, compared to the increase during the period since 1999 in which the higher education system has been gradually transformed to promote mass higher education. While it took about 20 years for the number of universities (*regular higher education institutions*) to increase from 598 in 1978 to 1,022 in 1998 (Li & Xing, 2010, p. 4), it just took another decade to more than double the number of universities to 2,263 in 2008 (Fig. 1). As regards the increase in the number of students, the difference in growth rate was even larger. While the number of newly enrolled students increased by about 5% annually from 0.4 million students in 1978 to 1.08 million in 1998 (Li & Xing, 2010), it increased by more than 43% (to reach 1.55 million) in just one year from 1998 to 1999. Over the period from 1999 to 2008, the number of newly enrolled students continued to increase at the very high annual growth rate of an average 19%. As a result of the large scale expansion of the university system, there were about 20.21 million university students in total in 2008 compared to just 3.41 million in 1998. In 2008, more than five million students graduated from university, more than six times the corresponding number in 1998. In total, about 6.7% of the Chinese population older than 6 (incl.) years of age were highly educated (with a university degree or higher) in 2008, compared to 2.8% in 1998.[5]

[5] These shares were calculated from official statistics that were obtained through the annual National Sample Survey on Population Changes which is based on a sample of roughly 1‰ of total population.

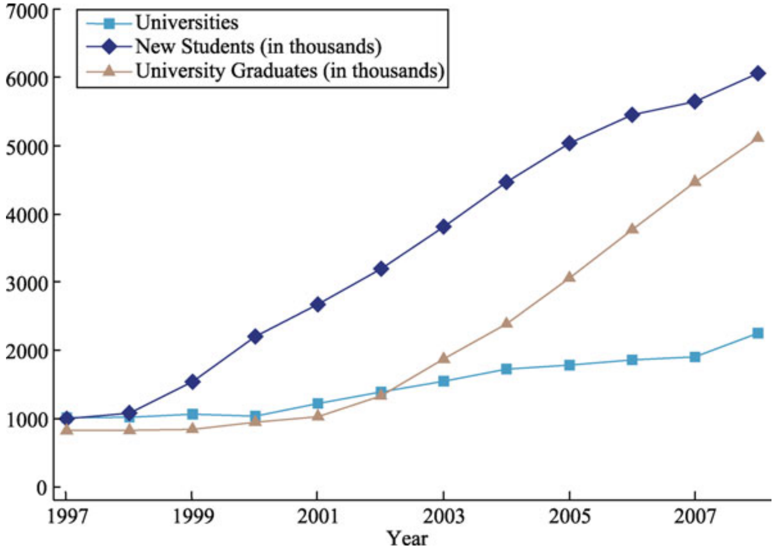


Fig. 1 Number of Universities, New Students (in thousands) and Graduates (in thousands) in China

Note. Based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press].

Classifying the 31 provinces of China into four regions (according to the regional economic policy classification)[6], there are substantial differences between these regions with respect to their size as well as to the levels of development of both the economy and the higher education system (Table 1). A comparison of the Coastal (Eastern) region, which is the most developed of the four regions, and the Western region, which is the least developed one, illustrates the magnitude of these differences (for the other two regions see Table 1). The Coastal region consists of 10 provinces that together account for roughly 10% of the geographic area of the Chinese Mainland and for about 37% of the total Chinese population (in 2008). It was the pioneer region of the Chinese economic reform and is China's economically most advanced region, with its GDP per capita roughly 1.6 times the national average (25,780 RMB[7]) in 2008. The region hosted the largest share of universities (40% of universities in 2008 up from 38% in 1998) and the greatest share of new students was enrolled at the universities in the Coastal region (40% in 2008 down from 43% in 1998).

---

6 See Footnote 4.

7 Using the average exchange rate of People's Bank of China for the year of 2008, this was roughly equal to US$ 3,710.

Table 1 Basic Data on Chinese Regions: Size, Economic Development, Higher Education System

	Provinces	Area	Population		GDP p.c.		Universities		New Students	
			1998	2008	1998	2008	1998	2008	1998	2008
Coastal	10	10%	34%	37%	166%	160%	38%	40%	43%	40%
North-Eastern	3	8%	9%	8%	106%	99%	14%	10%	13%	10%
Central	6	11%	29%	27%	69%	69%	23%	26%	23%	28%
Western	12	72%	29%	28%	59%	65%	24%	24%	21%	23%
Sum	31	100%	100%	100%	-	-	100%	100%	100%	100%

Note. Provinces: number of provinces belonging to region; Area, Population, Universities and New Students as shares of respective Chinese totals; GDP p.c.: GDP per capita relative to national GDP p.c. Based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1999. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1999. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press].

By contrast, the Western region, which consists of 12 provinces covering more than seven times the area of the Coastal region, is the economically least developed Chinese region. Its GDP per capita accounted for only about 65 % of the national level (or about 41% of the level of the Coastal region) in 2008. While the Western region's population size was about three fourths of that of the Coastal region in 2008 (about 85% in 1998), the number of newly enrolled students in the West was only about 58% of that of the Coastal region. More precisely, only about 24% of all universities were located in the West in 2008 (also 1998) and its share of newly enrolled students was only 23% in 2008 (up from 21% in 1998).

In sum, over the past decade of higher educational reform there has been a massive expansion of the scale of the university system. While the number of universities more than doubled in just one decade the number of newly enrolled students grew as much as six-fold and the number of university graduates followed with the corresponding three to four years delay. A first brief comparison of some aggregate figures for the most and the least advanced regions suggests that these massive changes may have come along with surprisingly small changes in the regional distribution of universities and of university students among the Chinese regions. Whether this first impression is supported or refuted by a more systematic data analysis and whether it can possibly be generalized to the distribution of higher education opportunities across individual provinces and (across and within) alternative groupings of provinces will be the subject of the next section.

Data and Method

Data

The empirical analysis is based on a panel dataset covering data on higher education for the 31 Chinese provinces, province-level municipalities, and autonomous regions (provinces, for short) and for a period of twelve years (1997–2008).[8] The data on higher education comprise, for each province, annual observations on the number of *regular higher education institutions* (universities, for short), the number of *newly enrolled students* (new students) and the number of *university graduates* in that province. As the development of the number of university graduates closely follows that of newly enrolled students with a time-lag of three to four years (see Fig. 1), the analysis is confined to the number of universities and new students. In addition, the dataset includes annual data on the size and economic performance of each of the 31 provinces. This includes information on the total population, the young population (population under age 15), the non-agricultural employment, and the GDP of the provinces. All data are collected from official sources, namely from various issues of the *Educational Statistics Yearbook of China* and of the *China Statistical Yearbook*.

Measuring Inequality

To investigate the inequality of higher education in China over time the appropriate inequality measures need to be applied. In economics, and the social sciences more generally, a large number of alternative inequality measures have been defined and applied to the analysis of various forms of inequality between (groups of) individuals. Among the most frequently applied inequality measures are the Gini coefficient, the coefficient of variation, and the generalized entropy

[8] There are two reasons why 1997 was chosen as the first year of the panel dataset for the analysis. First, in 1997 Chongqing was upgraded to be the fourth province-level municipality of China, next to Beijing, Tianjin, and Shanghai. Starting with 1997 thus enables to work on the largest balanced panel dataset, which was available at the time when data were collected. Second, starting with 1997 allows to have at least two years of data for the period before the large-sized scale expansion in higher education in China.

(GE) class of inequality measures, which includes, as its most prominent member, the so-called Theil index.

The members of GE class of inequality measures satisfy a number of normative criteria that are particular useful for the analysis here, and all inequality measures that satisfy these properties are ordinally-equivalent transformations of GE measures (Cowell, 2011, Sec. 3.4). Among these criteria, the additive decomposability of the inequality measure will be of key importance to the analysis.[9] Additive decomposability implies that, for any mutually exclusive set of subgroups of provinces (which may be defined on the basis of geographic (regional) or economic criteria), the total inequality across provinces can be meaningfully decomposed into the sum of the inequality *within* these subgroups and the inequality *between* these subgroups. This makes it possible to trace the overall changes in the inequality of higher education opportunities between provinces to changes in the corresponding inequality within and between meaningfully defined subgroups of provinces (e.g., larger geographic regions). In contrast to the members of the GE class of inequality measures, the Gini index does *not* satisfy this property.

The empirical analysis will be therefore based mainly on a specific member of the GE class of inequality measures, namely the so-called Theil index (or GE(1) index). To check the robustness of the results and conclusions two other frequently used members of GE class are applied, namely the GE(0),which is also known as the mean logarithmic deviation, and the GE(2), which is a simple monotonic transformation of the frequently used coefficient of variation (GE(2) = $0.5CV^2$).[10] As can be seen below, the results obtained for these other GE measures are, in general, qualitatively very similar to those obtained for the Theil index. In addition, as the Gini index is arguably still the most frequently used inequality index in the social sciences, the authors will also provide a comparison of at least some of the results obtained for the Theil index with those obtained by using the Gini index.[11]

[9] The other criteria satisfied by the GE class of inequality measures are the "weak principle of transfer," "scale independence," and the "principle of population" (for a discussion see Cowell, 2011, Section 3.4).

[10] The GE measures differ with respect to the weights they give to changes in the different parts of the distribution of the variable considered (here the supply of higher education opportunities). In comparison to the Theil index (GE(1)), the GE(0) is more sensitive to changes in the lower tail of the distribution, whereas the GE(2) is more sensitive to changes in the upper tail of the distribution.

[11] In the literature it has been shown by way of simulation studies that the Theil index and the Gini index generally lead to very similar results when ranking different distributions according to their implied levels of inequality (see K. Kuga "The Gini Index and the Generalized Entropy Class: Further results and a vindication," 1980, *The Economic Studies Quarterly*, (31), pp. 217–228). As shown below, this close similarity is also confirmed by the results of the analysis.

For the purpose of this paper, a slightly generalized form of the (traditional) Theil index will actually be used. This generalization, which has been introduced by Bickenbach and Bode (2008), will make it possible to better take into account the heterogeneity of provinces in terms of their population sizes or other relevant structural variables, while investigating the inequality in higher education in China. More concretely, following Bickenbach and Bode (2008), we define the generalised, *weighted relative Theil index* as follows:[12]

$$T^{wr} = GE^{wr}(1) = \sum_{i=1}^{I} w_i \frac{\frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \ln\left(\frac{\frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \right), \tag{1}$$

where I is the number of observations (in this case the 31 provinces) and X_i (i = 1, …, I) is the realization of the variable of interest (here the supply of higher education opportunities) for observation *i*. $\prod_i$ is referred to as the reference for observation *i* and w_i (with $\sum_i w_i = 1$) is referred to as the weight of observation *i*. The value of the *weighted relative Theil index*, T^{wr}, is equal to zero if $X_i / \prod_i$ is the same for all *i* (which here interpreted as perfect equality), otherwise it is strictly positive, with higher values of the index representing higher levels of inequality.[13]

For the special case of $\prod_i = 1$ and $w_i = 1/I$ for all *i* the traditional Theil index is obtained, which here is now called the *unweighted absolute Theil index*:

$$T^{ua} = GE^{ua}(1) = \frac{1}{I}\sum_{i=1}^{I} \frac{X_i}{\overline{X}} \ln\left(\frac{X_i}{\overline{X}}\right), \tag{2}$$

where $\overline{X}$ is the mean of the variable of interest over all observations, $\overline{X} = (1/I)(\sum_i X_i)$.[14] The *unweighted absolute Theil index*, T^{ua}, is equal to zero if X_i is the same for all $i = 1,\ldots,I$; and is strictly positive otherwise.[15]

The role of weights and references in the definition of the *weighted relative Theil index* can best be illustrated by comparing its definition as given by (1) to

---

[12] In the same way, Bickenbach and Bode (2008) have generalized the whole class of general entropy measures GE(α), including the GE(0) and GE(2) measures used for our robustness tests, as well as the Gini coefficient. See Appendix 1 for a definition of these measures.

[13] The upper bound of the weighted relative Theil index is given by UB(T^{wr}) = ln($1/w_{\min}$), where $w_{\min}$ is the smallest of the weights. It is obtained, if the variable of interest (i.e., for example, all universities) are completely concentrated in the smallest (in terms of weights) region.

[14] Indices with equal weights ($w_i = 1/I$) and general references are called *unweighted relative Theil indices*.

[15] The *unweighted absolute Theil index* takes its maximal value, UB(T^{ua}) = ln(I), if the variable of interest is completely concentrated in just one region. The same is true for the *unweighted relative Theil index*.

that of the *unweighted absolute Theil index*given by (2). The province-specific weights w_i, which replace the parameter *1/I* of (2), enables us to redefine the "basic units" of analysis and thus grant different weights to different provinces. For example, instead of giving each province the same weight as in the unweighted Theil index (2), every inhabitant of China is now given the same weight, which implies that the provinces are assigned different weights corresponding to their shares in total population when calculating the inequality measure. In other words, a given level of under- or oversupply (relative to the mean) of higher education opportunities in a specific province is given a greater weight in calculating the inequality measures, and is thus considered to contribute more to overall inequality, if that province is larger in terms of population relative to the other provinces.

The second difference between formulae (1) and (2) is the introduction of province-specific references $\prod_i$ in the definition of the *weighted relative Theil index* (1). These province-specific references make it possible to investigate the inequality across provinces of the distribution of universities or university places relative to relevant reference variables, which we consider important in assessing the (inequality of) higher education opportunities across the different provinces. The *unweighted absolute Theil index* without province-specific references, T^{ua} , takes its minimum value of zero, which is to be interpreted as perfect equality, if our variable of interest X, e.g., the number of universities or university places, takes the same value for all provinces ($X_i = \bar{X}$ for all i). The introduction of province-specific references $\prod_i$ allows us to redefine this perfect equality benchmark and the corresponding concept of equality. For example, taking the size of the (young) population in the different provinces as the reference implies that an equal distribution of university places is no longer defined as the case of an equal absolute number of university places in each province but as an equal ratio of university places to (young) inhabitants in each province. In other words, aiming for equality now implies that the number of university places in each province should be proportional to the size of the (young) population. More generally, the relative Theil index of inequality is zero (perfect equality) if the distribution of the variable of interest X across provinces is proportional to that of the reference variable, $\prod$, i.e., if $X_i/\prod_i$ is the same for all i.

In the empirical analysis of Section 4 (Regional Inequality of Higher Education Opportunities: Empirical Results) different specifications of weights and references will be used, thereby focusing on different facets of the issue of the inequality of higher education opportunities across Chinese provinces. As to the choice of weights both unweighted Theil indices ($w_i = 1/31$) as well as population-weighted Theil indices were calculated, where the weights of the individual provinces are given by their shares of total Chinese population. As to the choice of references, several alternative variables will be used—total population, population under age 15, non-agricultural employees and GDP (per capita)—that correspond to different supply side, demand side and development policy considerations on higher education opportunities. A discussion of the motivation for the different choices of weights and references and of their implications for the interpretation of the resulting measures is provided along with the presentation of our empirical results in Section 4.

As mentioned before, the decomposability property of the Theil index—and the GE inequality measures more generally—is explicitly made use of in order to trace changes in the inequality of higher education opportunities across all provinces to changes in the inequality *within* and changes in the inequality *between* subgroups of provinces, that was defined on the basis of geographic (four subgroups) and economic development (two subgroups) criteria.

Technically, the decomposition of the *weighted relative Theil index*, T^{wr}, into a within-group component and a between-group component is given by:

$$T^{wr} = T^{wr}_{within} + T^{wr}_{between}$$
$$= \sum_{r=1}^{R} w_r \frac{\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{\frac{X_i}{\Pi_i}}{\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i}} \ln \left(\frac{\frac{X_i}{\Pi_i}}{\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i}} \right), \quad (3)$$
$$+ \sum_{r=1}^{R} w_r \frac{\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \ln \left(\frac{\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \right)$$

where $r = 1,\ldots, R$ denotes the mutually exclusive (sub)groups of provinces, I_r denotes the set of provinces i belonging to region r, and $w_r = \sum_{i \in \mathrm{I}_r} w_i$.

The within-group component, T^{wr}_{within}, corresponds to the weighted average[16] of the levels of inequality between the provinces *within* each group $r (r = 1, \ldots, R)$, which are calculated based on the deviations of the relative higher education opportunities ($X_i/\prod_i$) of each province of a group from the corresponding weighted group mean. The between-group component, $T^{wr}_{between}$, corresponds to the inequality in the higher education opportunities between the groups and is

[16] Note that the sum of weights used for aggregating the R within-group measures to the within-group component equals 1; $\sum_{r=1}^{R} w_r \left(\sum_{i \in \mathrm{I}_r} \frac{w_i}{w_r} \frac{X_i}{\Pi_i} / \sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i} \right) = 1.$

calculated based on the weighted deviations of the different group means from the overall mean.[17]

Regional Inequality of Higher Education Opportunities: Empirical Results

Absolute Inequality

Aggregate statistics presented in Section 2 show that both the number of universities and the number of newly enrolled students (university places) have hugely increased since 1999. Against the background of such a strong scale expansion, the distribution of universities and university places between the most advanced (Coastal) and the least advanced (Western) regions in China seems to have changed only rather slightly between 1998 and 2008 (Table 1). However, when turning to a geographically more disaggregated level, even a brief look at the data shows that the number of universities, the number of students, and their changes over time differ quite substantially across Chinese provinces. In 1997, the first year of the observation period, there were only four universities in Tibet and five in both Ningxia and Hainan, but there were 65 universities both in Beijing and in Jiangsu. While there was a substantial increase in the numbers of universities in all provinces over the observation period, the differences across provinces remained substantial. In 2008, there were six universities in Tibet and nine in Qinghai but as many as 125 in Guangdong and in Shandong and even 146 in Jiangsu. The increase in the number of universities varied between 30.7% in Beijing (from 65 universities in 1997 to 85 in 2008) and 37.5% in Jilin (from 40 to 55) to about 206% in Anhui (from 34 to 104) and even 220% in Hainan (from 5 to 16). For almost two-thirds of provinces the number of universities increased between 100% and 200%.

As a measure of the overall inequality in the number of universities across provinces, for each year between 1997 and 2008, the *unweighted absolute Theil index* of the number of universities across provinces was first calculated. The development over time of this Theil index is displayed in Fig. 2 (line with hollow squares). The value of the Theil index slightly decreased from 0.153 in 1997 to 0.143 in 2008, with a maximum (minimum) value of 0.160 (0.131) in the year 1999 (2003). There is thus only little change and no clear time trend in the measure between 1997 and 2008.

---

[17] Similar decomposition formulas hold for the GE(0) and the GE(2) measures, which are used for robustness analyses in Section 4 (in the case of the GE(2) index, the weights used for aggregating individual within-group measures to the within-group component do not sum up to 1, however). By contrast, no such decomposition exists for the Gini index.

As universities differ in size (the number of students), the number of universities in a province is obviously only a very rough measure of the opportunities for potential students to obtain higher education in the different provinces. It is therefore preferable to look at the distribution of the number of newly enrolled students. Fig. 2, also displays for each year, the *unweighted absolute Theil index* of the distribution of newly enrolled students across provinces (line with filled squares). A comparison of the two measures shows that the inequality, or concentration, of newly enrolled students across provinces is substantially larger than that of the number of universities both in 1997 and in 2008.[18] Actually the total number of newly enrolled students varies from 717 in Tibet and 2,619 in Qinghai to 58,168 in Hubei and 78,424 in Jiangsu (more than 100 times the number of Tibet) in 1997 and from 8,520 in Tibet and 13,767 in Qinghai to 410,705 in Jiangsu and as many as 465,593 in Shandong in 2008.

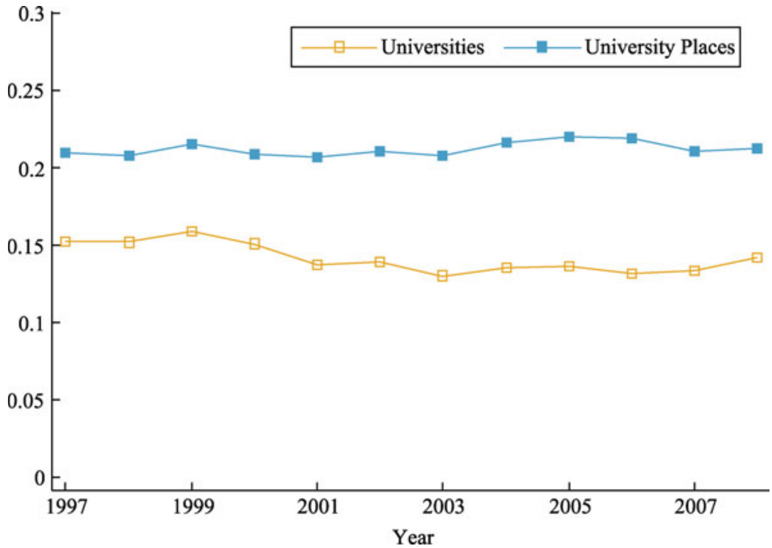


Fig. 2 Inequality in Distribution of Universities and University Places across Provinces (Unweighted Absolute Theil index)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press].

Similar to the concentration of universities, the concentration of newly enrolled students across provinces is fairly constant over time. The *unweighted*

[18] This indicates that universities are on average larger, in terms of newly enrolled students, in provinces with high numbers of universities as compared to provinces with low numbers of universities.

absolute Theil index of newly enrolled students increased only very slightly from about 0.210 in 1997 to 0.213 in 2008,with a maximum (minimum) value of 0.220 (0.207) in the year 2005 (2001). This reflects the fact that—despite very high absolute growth rates in the number of newly enrolled students—the *distribution* of the 31 provinces' *shares* of all newly enrolled students remains *overall* fairly constant over time.[19] As for the number of universities, this does not imply that there was no change in the number of newly enrolled students or in the shares of individual provinces in the total number of students newly enrolled, it rather suggests that the increase in the number of students was overall "quite" proportional, i.e., similar in relative terms, across provinces. This is true although the increase in the number of newly enrolled students varies from about 173% in Beijing (from 57,124 to 156,092) and 216% in Shanghai (from 45,371 to 143,328) to 884% in Hainan (from 4,038 to 39,735) and 1,088% in Tibet (from 717 to 8,520). Still for almost two-thirds of provinces the increase from 1997 to 2008 in the number of newly enrolled students lies between 400% and 600%.

Relative Inequality

The analysis so far does not consider differences in the size of the population of the different provinces. As the population sizes of Chinese provinces vary very substantially—in 2008 the population size varied between slightly less than three million in Tibet and about 94 million in Shandong—it can hardly be considered a reasonable political objective to have an equal or similar absolute number of universities or university places (or students) in all provinces, disregarding the differences in their size. In discussing the inequality in the supply of higher education opportunities across provinces one should therefore have to take into account the differences in the sizes of the different provinces; and in evaluating changes in inequality over time one also has to take into account that the population of provinces are growing at grossly different rates, so that the relative sizes of the provinces as measured by their shares in overall population are also changing over time. For example, while population shrank by about 6.7% in Chongqing and by about 3.5% in Sichuan it increased by about 35% in Guangdong and by about 37% in Beijing over the time period considered.

As explained in Section 3 (Data and Method), there are basically two

[19] Qualitatively quite similar results as for the Theil index—the concentration of newly enrolled students is larger than the concentration of universities; both concentration measures are fairly constant over time—are obtained for the two alternative general entropy (GE) measures, namely for the GE(0) and GE(2) as well as for the Gini index (see Fig. A1 in Appendix 2).

mutually non-exclusive ways in which the analysis can account for provinces' different population sizes. The first way is to consider the distribution across provinces of universities per capita (or newly enrolled students per capita) rather than the distribution of the absolute number of universities (or newly enrolled students). In the terms of Section 3, this amounts to taking provinces' population size as the *reference* in calculating relative Theil indices. The other way is to *weight* provinces by the size of their population when calculating the index. Instead of provinces as in the *unweighted Theil index* it is the individual inhabitants that are given equal weights in calculating the population-weighted Theil index. This implies that the undersupply of universities or university places in a given province is taken to be a larger deviation from an equal supply, and thus a potentially larger problem for equality, if this province is larger in terms of population.

Fig. 3 displays for each year between 1997 and 2008 the unweighted relative and the population-weighted relative Theil indices both for the number of universities and for the number of newly enrolled students. Bearing the findings from Fig. 2 in mind, there is a number of important observations from Fig. 3.

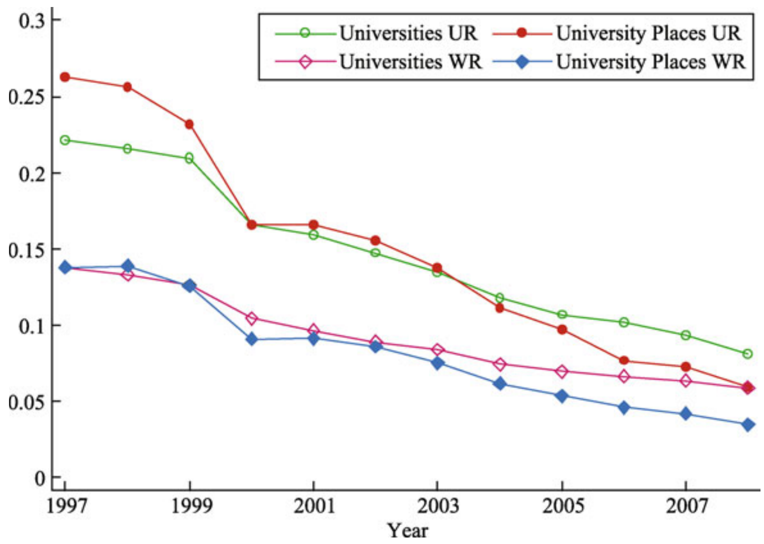


Fig. 3 Inequality in Distribution of Universities and University Places across Provinces Relative to Population Size (Unweighted Relative (UR) and Population-Weighted Relative (WR) Theil indices)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press];

Firstly, at the beginning of the observation period, the *unweighted relative Theil indices* for both the number of universities (hollow circles) and the number of newly enrolled students (filled circles) were even higher than the corresponding *unweighted absolute Theil indices* displayed in Fig. 2. This implies that in 1997 universities and university places were even more unequally distributed across provinces once we consider their supply relative to the provinces' different population sizes.

Secondly, the *weighted relative Theil indices* for both the number of universities (hollow diamond) and the number of newly enrolled students (filled diamond) are lower—in the early years even substantially lower—than the corresponding unweighted relative measures.[20] They are also lower than the corresponding absolute measures. The lower values for the population-weighted as compared to the unweighted relative indices indicate that deviations from the average number of universities or students per inhabitant are on average more pronounced in smaller provinces (for more on this see below).

Thirdly—and this is the most important observation from Fig. 3, and the most striking difference to Fig. 2—there is a strong and fairly monotonic decline over time of all relative Theil indices displayed in Fig. 3.[21] As a consequence these relative inequality measures are substantially lower than the corresponding absolute measures (Fig. 2) at the end of the observation period. Generally, the decline in inequality is stronger for the number of newly enrolled students than for the number of universities. It is also slightly stronger for the unweighted measures (circles) than for the weighted measures (diamonds).[22]

The strong decline in the relative measures suggests that the inequality across provinces in the supply of higher education opportunities per capita has

[20] In later years of the observation period, inequality was higher for the number of universities than for the number of newly enrolled students for both the weighted and the unweighted measures. This suggests that universities were on average larger (in terms of newly enrolled students) in larger provinces (in terms of population).

[21] For most of the inequality measures displayed in Fig. 3, there is a particularly strong decrease in inequality between 1999 and 2000 (similar effects for several of the measures discussed in the further course of the analysis can be seen). This particularly strong decrease is partly due to an extreme variation in the population data for some of the provinces for the year 2000. This is also the reason why a corresponding decline for 2000 has not been observed for the absolute indices displayed in Fig. 2 that do not make use of these population data.

[22] Again the results obtained for our alternative inequality indices, GE(0), GE(2), and Gini indices, are qualitatively quite similar to those obtained for the Theil index. Generally, inequality figures obtained from the different indices are highly correlated over time. The pairwise correlation between the weighted relative Theil index and the weighted relative Gini index, for example, is higher than 0.99 for the number of universities and higher than 0.98 for the number of newly enrolled students. For a graphical comparison of the different weighted relative measures, see Fig. A2 in Appendix 2.

decreased substantially between 1997 and 2008. While there are some quantitative differences between the development in the concentration of universities per capita and the concentration of newly enrolled students per capita, the general development is the same for both variables, both have decreased substantially over time. In the following discussion the focus therefore will be put on only one of the two variables. Given that universities may be of very different sizes, the number of newly enrolled students or university places is generally a better proxy for the supply of higher education opportunities than the number of universities. In what follows, therefore, a focus will be put on the concentration of newly enrolled students.

The *weighted relative Theil index* for the number of newly enrolled students (filled diamonds) decreased substantially between 1997 and 2008 (from 0.138 to 0.035). The corresponding *unweighted relative Theil index* (filled circles) is larger and decreased slightly more strongly (from about 0.263 in 1997 to about 0.059 in 2008). The decrease of the two indices indicates a decline in the inequality across provinces of the number of newly enrolled students per capita. For example, in 1997 there were as few as 29 newly enrolled students per 100,000 inhabitants in Tibet and just 36 per 100,000 inhabitants in Guizhou while the corresponding numbers were 311 in Shanghai and 461 in Beijing. In 2008 this ratio was higher in all provinces; it was the lowest in Guizhou with 226 and Yunnan with 243 and the highest in Beijing with 921 and Tianjin with a ratio of 944. While the differences in these ratios across provinces were still quite substantial in 2008 they were much smaller than in 1997 (in relative terms). The higher values of the unweighted as compared to the weighted Theil index reflects the fact the provinces with the lowest and those with the highest number of newly enrolled students per capita are generally of comparatively small (Tibet, Tianjin, Beijing, Shanghai), or medium (Guizhou, Yunnan) size in terms of their population while the student to population ratios in the large provinces are closer to the average values across provinces.

Given the difference identified between the results for the absolute inequality indices (Fig. 2) and the results for the relative inequality indices (Fig. 3), we may wonder whether the results for the relative indices—in particular the strong decrease of inequality over time—hold true for alternative reference variables that may be equally well or even better suited for our research purpose than the provinces' total population sizes. Two alternative references are (i) the size of the population under age 15 and (ii) the number of non-agricultural employees. Given differences in the age structure of the provinces, the size of the population under 15 as a proxy of the size of the young population may be considered a better indicator of the regional supply of potential students and thus the demand for university places than the overall population size. Similarly, given differences in the (structural) economic development of the provinces the number of non-agricultural employees may be considered a better indicator of the demand for higher education graduates in the provinces' labour markets than the overall population.[23]

Fig. 4 displays the *relative weighted Theil indices* for the number of newly enrolled students for these two alternative references (filled circles for population under age 15 and filled squares for non-agricultural employment). For ease of comparison, Fig. 4 also displays once again the *relative weighted Theil index* with the population size as the reference (filled diamonds) from Fig. 3. For all three Theil indices provinces' total populations were taken as weights as before. The

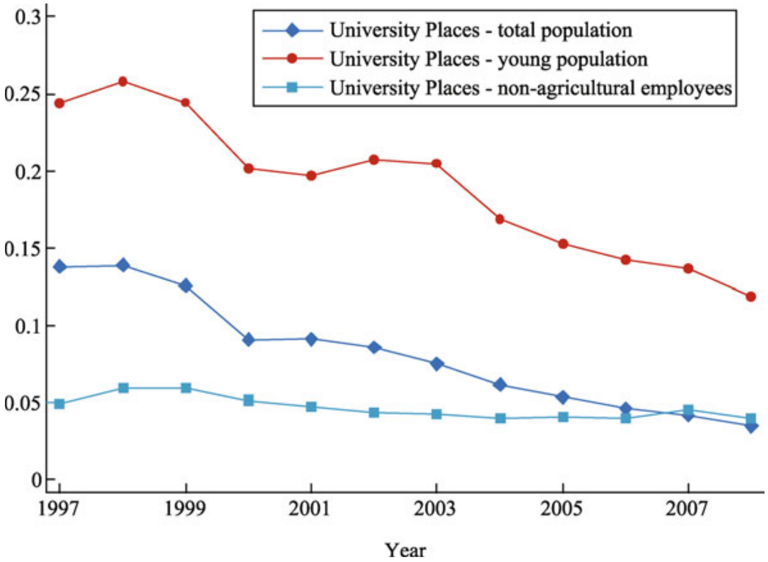


Fig. 4 Inequality in Distribution of University Places across Provinces Relative to Alternative Size Measures (Population-Weighted Relative Theil Indices)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press];

---

[23] The choice of *non-agricultural* employment as a proxy for the demand for high-skilled workers is justified by the fact that manufacturing and services are more high-skill intensive than (traditional) agriculture (National Bureau of Statistics of China, 2009, "中国人口和就业统计年鉴" [*China Population and Employment Statistics Yearbook*]. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press]). This tendency is likely to be reinforced by the government-promoted shift towards the production of more technologically advanced products and an increasing importance of more complex, knowledge-intensive services.

choice not to use the population under age 15 or the non-agricultural employment as weights is based on the presumption that an adequate supply of higher education opportunities is in the interest of the whole population (and not just the young population or non-agricultural employees).[24]

From Fig. 4 it can be observed that the *weighted relative Theil indices* for all three references are falling between 1997 and 2008.[25] While the decline in the index with total population as reference was particularly strong (75% in relative terms), the absolute decline in the index with non-agricultural employment as reference was comparatively small. Nevertheless, this index was still more than 18% smaller in 2008 than in 1997. As compared to its maximum value in 1998 (0.059) the relative decline was even more than 33%. Taken the population under age 15 as reference, the Theil index declined by about 51%. The results for the alternative reference variables thus confirm the observation that the regional inequality in the supply of university places has strongly decreased between 1997 and 2008 once the provinces' vastly different population sizes (relative measures) are taken into account. While the decrease was somewhat weaker for the alternative references as compared to the population reference, it was still quite considerable in relative terms.

Comparing the *levels* of inequality, Fig. 4 shows that the inequality across provinces was substantially *larger* for the number of newly enrolled students per inhabitant under age 15 than for the number of newly enrolled students per inhabitant. In contrast, relative to the number of non-agricultural employees the inequality across provinces of the number of newly enrolled students was much *lower* than the inequality relative to the size of total population in the early years of the observation period. Both measures were of similar size at the end of the observation period, however. The differences in the levels of the Theil indices for the three references are reflected by corresponding differences in the span of values of the relative numbers of newly enrolled students. For the number of newly enrolled students per inhabitant under age 15 the span between the maximum and the minimum ratio across provinces is much higher in relative terms than the corresponding span for the number of newly enrolled students per inhabitant which again is much higher than the span for the number of newly

[24] The *unweighted relative Theil indices* were calculated for the three references as well as the corresponding weighted and unweighted Theil indices for the number of universities. The results of these calculations, which are not presented here, are largely in line with the results presented here.

[25] In contrast to Liu (2007), who observes an increase in the inequality of the number of students relative to provinces' young population in the year 2006 (the last year of his observation period), here such an increase is not observed. For both the young population reference and the total population reference there is a decrease of the weighted relative Theil index in 2006 (and neighboring years).

enrolled students per non-agricultural employee.[26]

These differences result from the "structural" differences between those provinces that have high ratios of students per capita and those that have low ratios. Provinces with comparatively high students per capita tend to have an older population and a larger share of manufacturing and service sector employment. Compare, for example, the provinces that have the lowest numbers of students per capita, namely Tibet and Guizhou in 1997 and Guizhou and Yunnan in 2008, with those provinces that have the highest number of students per capita, namely Shanghai and Beijing in 1997 and Tianjin in 2008. Tibet, Guizhou and Yunnan still have a much higher share of young people in the total population and they also still have a much higher share of agriculture in total employment compared to Shanghai, Beijing and Tianjin. Both with respect to the demographic change towards an older population and with respect to the structural transition of the economy from agriculture to manufacturing and services the first group of provinces is clearly lagging behind the average Chinese province, whereas the second group is leading the Chinese average in these transition processes. Across all provinces, there is a strong (but decreasing) negative correlation between the share of population under age 15 in the total population and the share of non-agricultural employment in total employment.[27] The share of non-agricultural employment in total employment tends to be largest in the Eastern/Coastal provinces where the opening of the Chinese economy and the accompanying economic reform process started and where structural change and income growth have been strongest. At the same time, these provinces tend to have a larger share of adults in total population due to a stricter enforcement of the One-Child Policy and the immigration of workers (and students) from less advanced, poorer provinces.

Relative Inequality within and between Regions

The results displayed in Fig. 4 have clearly shown that taking into account the provinces' highly different (population) sizes, the inequality across the 31

[26] The number of newly enrolled students per 100,000 inhabitants under age 15 ranges from 88 in Tibet to as many as 2,738 in Beijing in 1997 and from 855 in Guizhou to 9,628 in Beijing in 2008, corresponding to a ratio between minimum and maximum of about 1:30 in 1997 and 1:11 in 2008. By comparison, the number of newly enrolled students per 100,000 non-agricultural employees ranges from 209 in Zhejiang to 968 in Beijing in 1997 and from 782 in Guizhou to 2,612 in Tianjin in 2008 corresponding to a ratio of less than 1:5 in 1997 and close to 1:3 in 2008. For the total population reference the corresponding ratios were about 1:12 in 1997 and more than 1:4 in 2008 (for detailed figures see above).

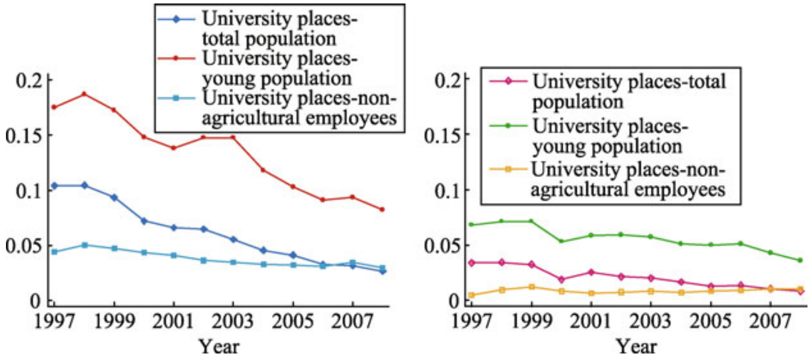
[27] The correlation coefficient between the two ratios has been –0.84 in 1997 and –0.52 in 2008.

Chinese provinces in the number of newly enrolled students, as measured by the (population-) *weighted relative Theil index*, has clearly decreased since 1997. In principle, such a *decline* in the overall inequality across provinces may go along with an *increase* in the inequality between larger regions (or groups of provinces), such as between the comparatively well-developed coastal provinces on the one hand and the less developed central or western provinces on the other hand. To see whether this is actually the case the regional classification used by the Chinese government to design its regional development policy was adopted, which assigns the 31 provinces, according to their geographical location and developing status, into four regional groups: the Eastern or Coastal region, the North-Eastern region, the Central region, and the Western region (see Footnote 4). Making use of the decomposition properties of the Theil index (see Section 3), each of the three Theil indices from Fig. 4 were decomposed into a within-group component and a between-group component. For each of the three references the within-group component is equal to the weighted average of the four (respective) relative Theil indices across the provinces within each of the four regions. It is a measure of the average inequality in the number of newly enrolled students across the provinces within the individual regions. The between-group component is equal to the *weighted relative Theil index* of inequality across the four regions. It is a measure of the inequality in the number of newly enrolled students across the four regions. Fig. 5 displays the resulting within-region components (left panel) and between-region components (right panel) for each of the three weighted relative Theil indices from above.[28]

For all three references the *within-region component*, which is in all cases substantially larger than the *between-region component*, declined strongly between 1997 and 2008. For the *between-region component* there is a similar decline for the total-population reference (hollow diamonds) and young-population reference (hollow circles). In contrast, relative to the number of non-agricultural employment the between-group inequality of newly enrolled students increased between 1997 and 2008. Actually, for this reference the between-region measure was about twice as high in 2008 as in 1997, whereas the within-region measure has decreased by about a third. While the between-region inequality for non-agricultural employment was comparatively low in all years and took its highest value in 1999, where it was slightly higher than in 2008, the development of this between-group inequality might nevertheless raise concerns that the regional inequality in higher-education opportunities may actually increase in the (unequal) process of economic

[28] Thus the *weighted relative Theil index* with population size as reference (filled diamonds in Fig. 4) is, for instance, equal to the sum of the corresponding within-group (filled diamonds in Fig. 5) and between-group components (hollow diamonds in Fig. 5).

development in China.



(a) Within-Region Inequality (b) Between-Region Inequality

Fig. 5 Inequality in Distribution of University Places across Provinces: Decomposed by Four Regions (Population-Weighted Relative Theil Indices from Fig. 4)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press].

Inequality in Higher Education and Regional Economic Development

In further investigating this issue it is useful to take differences in provinces' economic development, measured by GDP per capita of Chinese provinces, more directly into account both in defining the reference of the inequality measure and in defining groups of regions for our decomposition analysis. Thus the weighted relative Theil indices were calculated for the number of *newly enrolled students per capita* with the *GDP per capita* as reference. As in the previous section, the population shares were used as weights. The set of 31 provinces was divided into two groups for analysis: the "poor provinces" comprising the 16 provinces with per capita GDP at or below the GDP per capita of the median province in 1997, and the "rich provinces" comprising the 15 provinces with GDP per capita above that of the median province in 1997.[29] This distinction into a group of poor provinces (group 1) and a group of rich

[29] While the two groups are not defined geographically but by their GDP per capita, the classification is correlated with the above classification into four geographically defined groups. Actually all Western and Central provinces with the exception of Hubei and Xinjiang belong to the group of poor provinces, whereas all Eastern/Coastal and North-Eastern provinces belong to the group of rich provinces.

provinces (group 2) was used to calculate the corresponding within- and between-groups Theil indices. This allows us to investigate how the inequality in the number of newly enrolled students per capita over GDP per capita evolved both between and within the groups of rich and poor provinces. The corresponding weighted relative Theil indices across all 31 provinces and the between-and within-group components are displayed in Fig. 6. In addition, Fig. 7 displays the weighted relative Theil indices for the two groups, the group of "poor provinces" and the group of "rich provinces"; for ease of comparison it also displays again the between-group component from Fig. 6.[30]

From Fig. 6 it can be seen that the *weighted relative Theil index* (filled squares) takes a value of about 0.06 both in 1997 and in 2008 with some fluctuation, but no clear trend, in between these two years. Comparing this value to the values of the three weighted relative Theil indices displayed in Fig. 4, it

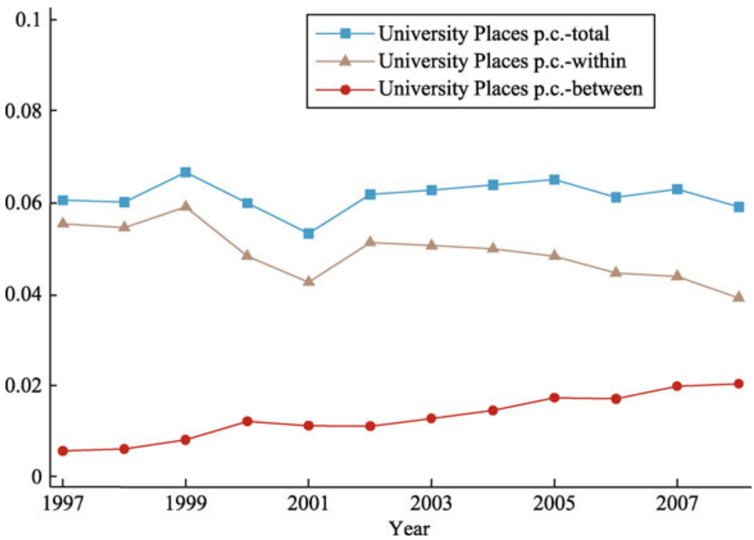


Fig. 6 Inequality in Distribution of University Places p.c. across Provinces Relative to GDP p.c.: Decomposed by Two Income Groups (Population-Weighted Relative Theil Index)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press].

[30] The within-group Theil index displayed in Fig. 6 is thus the weighted average of the Theil indices for the two income groups displayed in Fig. 7.

can be noted that it is considerably lower than the Theil index with population under age 15 as the reference; it is also considerably lower than the measure with total population as the reference in the early years of the observation period, but higher than this measure at the end of the observation period. Overall the level of the Theil index of newly enrolled students per capita over GDP per capita (from Fig. 6) is more similar in size, though somewhat larger, than the Theil index for the non-agricultural employment reference from Fig. 4.[31]

The fact that the relative inequality measure with GDP as reference is largely constant over time is in clear contrast to the decline over time of all of the relative measures from Fig. 4. While the decline in inequality was less pronounced for the non-agricultural employment reference than for the population and the population-under-15 references, it was still significant for that reference as well. From the decomposition analysis it can be seen that the (relative) constancy over time of the inequality of the number of newly enrolled students per capita over GDP per capita is the result of two quite different development of the corresponding inequalities within and between our groups of “rich” and “poor” provinces. While the measure for the within group-inequality (filled triangles) has decreased over time, the measure for the between-group inequality (filled circles) has increased over time.[32] From Fig. 7 it can be seen, in addition, that the decline in the within-group component corresponds to a decline of inequality within both income groups. The inequality within the group of provinces with low GDP per capita (filled circles) declined quite considerably, and rather monotonically, over time. The inequality within the group of provinces with comparatively high GDP per capita (filled diamonds)—which was substantially larger than the inequality within the other group—was also higher in 1997 than in 2008, it exhibited a clear downward trend only after 2004, however.

Of particular interest for the issue of the inequality of higher education opportunities in the development process is the development over time of the

[31] The similarity of the values of the latter two measures reflects the fact that structural change of employment away from agriculture towards manufacturing and services and the increase in GDP per capita go largely hand in hand in the economic development process. More technically, for each year the correlation between the level of non-agricultural employment and GDP across provinces is close to 0.9.

[32] The corresponding unweighted measures were also calculated for robustness checks. The trends over time for both the between-group component (increasing) and the within-group component (decreasing) are the same for the unweighted measure as for the weighted measure. As the increase of the between-group component is somewhat weaker and the decrease of the within-group component somewhat stronger for the unweighted measure, however, the overall unweighted relative Theil index for the GDP reference declined between 1997 and 2008 (from about 0.07 to about 0.057), whereas the corresponding weighted index displayed no such trend.

between-group component. Starting from a (very) low level the between-group components increased very considerably at least in relative terms (Fig. 6). The between-group component accounted for only about 8.6 % of the overall Theil index in 1997 but for more than one third (about 34 %) of the overall Theil index in 2008.

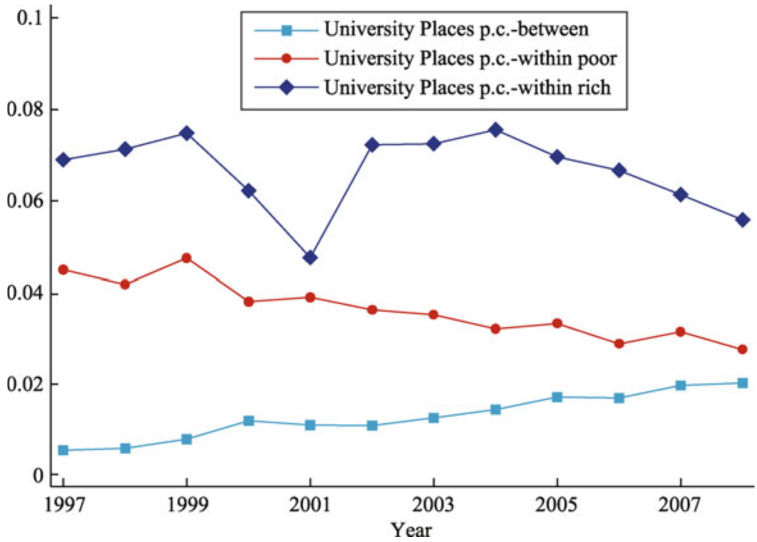


Fig. 7 Inequality in Distribution of University Places p.c. across Provinces, Relative to GDP p.c.: Between and within Individual Groups (Population-Weighted Relative Theil Index)

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press].

The level of the between-group inequality (and its increase over time) alone does not indicate whether the supply of higher education opportunities was relatively larger in the poor or in the rich regions. Additional calculations[33] show, however, that the ratio of newly enrolled students per capita to GDP per capita was *larger* on aggregate for the group of poor provinces than for the group of rich provinces for all years, and that the difference between the groups has increased considerably over time (in relative terms). While the ratio was about 20% larger for the poor provinces than for the rich provinces in 1997 that

[33] Detailed figures can be obtained upon request.

relation was almost 60% in 2008.[34] It can also be shown that this increase is not due to a particularly strong increase of GDP per capita in the rich provinces. Actually, GDP per capita has increased slightly more strongly in the poor provinces (305% between 1997 and 2008) than in the rich provinces (286%). The difference in the increase in the number of newly enrolled students per capita was much larger, however. It was about 580% (from 60 students per 100,000 inhabitants to about 410 per 100,000) in the poor provinces and about 395% (from 104 students per 100,000 inhabitants to 517 per 100,000) in the rich provinces. Thus, while the number of newly enrolled students per 100,000 inhabitants was about 73% higher in the rich provinces than in the poor provinces in 1997, that ratio shrank to slightly more than 25% in 2008. At the same time, the GDP per capita was still about twice as high in the rich provinces as in the poor ones.

Summary and Discussion

In light of increasing global competition and rising labor costs the Chinese government, by the end of the 1990s, recognised innovation and upgrading of production processes as crucial for the Chinese economy's ability to sustain its high-speed economic growth in the future. And it also recognised the importance of a highly qualified labor-force for the success of its innovation and upgrading strategy. To increase the provision of highly qualified labor and to improve the average educational level of the population, the Chinese government has continuously reformed the higher education system. It attempted to transform the higher education system from one focusing on elite education to one promoting mass education through a substantial scale expansion of higher education. Between 1998 the last year before the expansion and 2008 the number of newly enrolled students grew six-fold. Along with the massive increase in higher education opportunities in general, the Chinese government intended to narrow the gap between the differing higher education opportunities across Chinese provinces as part of its regional development strategy. The poor Western provinces, in particular, were supposed to receive

[34] Dividing each of the two groups of provinces further into two sub-groups, it can be seen that the ratio of students per capita to GDP per capita is also higher for the eight poorest provinces than for the richer eight of the 16 poor provinces, and it is higher for the eight poorer of the rich provinces than for the seven richest provinces. (It is also higher for the richer of the poor provinces than for the poorer of the rich provinces). However, the difference in the ratio between the poorest provinces and group of richer of the poor provinces has declined between 1997 and 2008; the difference between the poorer of the rich provinces and the richest provinces has also declined, if only slightly, after 2003, but has increased before.

preferential treatment and specific support from the government in this regards.

Using a balanced provincial panel dataset from 1997 to 2008, the authors empirically analyzed the level and development over time of the inequality in the distribution of higher education opportunities across the Chinese provinces in general, and across groups of provinces with different development levels in particular. To do so, a series of generalised (weighted relative) Theil indices were calculated, which made it possible to explicitly consider the heterogeneity in the provinces' sizes and structural development levels.

The differences in the results obtained for the absolute Theil index and alternative unweighted and population-weighted relative Theil indices clearly demonstrate the importance of these considerations. For both universities and university places (newly enrolled students) the absolute Theil index of inequality stayed roughly constant over time. Disregarding the substantial differences in provinces' sizes, the scale expansion did not seem to make any significant contribution to the reduction of regional higher education inequality. However, it can hardly be considered a reasonable political objective to have an equal or similarly absolute number of universities or university places (or students) in all provinces, disregarding their differences in size. The analysis was therefore proceeded by calculating the unweighted and population-weighted Theil indices for the inequality of the distribution of university places relative to different proxies for provincial size: total population, young population and non-agricultural employees. Irrespective of the specific size proxy considered, the relative Theil indices displayed a clear downward trend over the research period, implying that university places actually became more equally distributed among provinces during the scale expansion period, when taking different provincial sizes, and thus potentially different levels of demand for higher education, into account. Making use of the decomposability property of the Theil index and focusing on the population-weighted relative Theil indices it was also found that the regional inequality of university places *within* the four regions (Coastal, Central, Western and North-Eastern) decreased on average, irrespective of the specific size reference. Regarding the inequality *between* the four regions the finding was less conclusive, however. While the between-region inequality decreased when considering total population and young population as references, the between-region inequality of university places increased relative to non-agricultural employment. The corresponding value—though comparatively low in absolute terms—was actually about twice as high in 2008 as it was in 1997. This increase in between-region inequality may give rise to concerns that the disadvantage of poorer, less developed regions in terms of higher-education opportunities may have increased, rather than decreased as intended by the government, during the period of the expansion of the higher education system in China.

To investigate the issue of higher education inequality and unequal economic development across provinces more directly, the (population-weighted) Theil index of university places per capita relative to GDP per capita and its decomposition in the inequality within and between comparatively “rich” and “poor” provinces were calculated. The overall index turned out to be relatively constant over time suggesting that the inequality in the distribution of university places per capita relative to the economic development of provinces did not decrease during the expansion period. The decomposition analysis showed, however, that the relative constancy over time of the inequality of the number of university places per capita over GDP per capita is the result of opposing developments of the corresponding inequalities within and between groups of rich and poor provinces. While the within-group inequality decreased over time, the between-group inequality increased. This increase was not realized at the expense of poor provinces, however. Quite the contrary, the increase in between-group inequality was driven by a much stronger increase in the number of university places per capita in the poor provinces than in the rich provinces. The relative difference of university places per capita between the rich and the poor regions decreased from 1.73:1 in 1997 to 1.25:1 in 2008.

In sum, the empirical analysis showed that, during the period of rapid expansion of the higher education system, the inequality in the distribution of higher education opportunities across different provinces in China decreased, when taking into account the substantial differences in the sizes of provinces. It also showed, that the inequality in the provision of university places per capita relative to GDP per capita between the poor and rich provinces increased and that this increase was in favor of the poor provinces, which realised an increasing advantage over rich provinces with respect to the number of university places relative to GDP (and a corresponding decline in their disadvantage with respect to the number of university places per inhabitant).

These results are largely consistent with the announced (regional) development priorities of the Chinese government, which intended to massively expand the scale of the higher education system and at the same time reduce the inequality of higher education opportunities in favor of backward provinces. The analysis and the findings of the paper contribute to the ongoing public debate on the unequal higher education opportunities across provinces in China. Our analysis focused on the purely quantitative but nonmonetary aspect of the distribution of higher education opportunities, based on two university-related variables, namely the number of universities and the number of newly enrolled students. The monetary aspect (financial investment in higher education) and the qualitative aspect of inequality of higher education opportunities across Chinese provinces have been left for future research. The third even more fundamental issue that has not been addressed in this paper but been left for future research is the question of whether a more equal distribution of higher education opportunities across provinces in general and a preferential treatment of the least developed Western region in particular may really be considered an effective or even economically efficient way to promote sustainable economic growth in general and economic convergence between provinces in particular.

Acknowledgements The authors would like to thank Michaela Rank for her excellent research and technical assistance. Wan-Hsin Liu would also like to thank the German Research Foundation (DFG) for its financial support of the cooperative project *Regional Agility and Upgrading in Hong Kong and the PRD* and of the cooperative project *Regional Agility in the Wake of Crisis: Towards a New Growth Model in the Greater Pearl River Delta (Priority Program 1233: Megacities-Megachallenge: Informal Dynamics of Global Change)*.

References

Bickenbach, F., & Bode, E. (2008). Disproportionality measures of concentration, specialization, and localization. *International Regional Science Review*, *31*(4), 259–288. doi: 10.1177/0160017608319589

Central Committee of the Communist Party of China. (1985). 中共中央关于教育体制改革的决定 [Decisions on reforming the educational system]. Retrieved January 17, 2013, from. http://news.xinhuanet.com/ziliao/2005-02/06/content_2554936.htm

Central Committee of the Communist Party of China. (1993). 中国教育改革和发展纲要 [Guidelines for educational reform and development]. Retrieved January 17, 2013, from http://baike.baidu.com/view/486179.htm

Central Committee of the Communist Party of China. (1999). 关于深化教育改革, 全面推进素质教育的决定 [Decisions on deepening the educational reform to improve the quality of education]. Retrieved January 17, 2013, from http://www.edu.cn/zong_he_870/20100719/t20100719_497966.shtml

Central Committee of the Communist Party of China. (2003). 关于实施东北地区等老工业基地振兴战略的若干意见 [Advice on implementing the strategy to revitalise the old industrial base in the North-Eastern region of China]. Retrieved January 21, 2013, from http://www.chinabaike.com/law/zy/0978/1419299.html

Central Committee of the Communist Party of China. (2006). 中共中央国务院关于促进中部地区崛起的若干意见 [Advice on the promotion of the development in the Central region of China]. Retrieved January 21, 2013, from http://cpc.people.com.cn/GB/64184/64186/207393/13296342.html

Chen, T. Z. (2004). 在公平与不公平之间: 论高等教育的地区差异 [Between fairness and unfairness: A discussion on regional difference of higher education]. 教育发展研究 [*Exploring Education Development*], *24*(9), 84–86.

Cowell, F. A. (2011). *Measuring inequality* (3rd ed.). Oxford, England: Oxford University Press.

Cowell, F. A., & Flachaire, E. (2007). Income distribution and inequality measurement: The problem of extreme values. *Journal of Econometrics*, *141*(2), 1044–1072. doi:

10.1016/j.jeconom.2007.01.001

Dong, Z. F., & Shen, B. F. (2000). 教育经济区域划分与高教投资差异分析 [Analysis of educational economic zone classification and higher education investment difference]. 华中师范大学学报（人文社会科学版）[*Journal of Huazhong Normal University (Humanities and Social Sciences*)], *39*(3), 20–28. doi: 10.3969/j.issn.1000-2456.2000.03.004

General Office of the Central Committee of the Communist Party of China. (2004). 贯彻落实中央关于振兴东北地区等老工业基地战略进一步加强东北地区人才队伍建设的实施意见 [Advice on implementing the strategy to revitalise the old industrial base in the North-Eastern region of China and on progressing the development of human capital in the North-Eastern region]. Retrieved January 17, 2013, from , http://renshi.people.com.cn/GB/140384/184744/184868/11386021.html

General Office of the State Council of the People's Republic of China. (2001). 关于西部大开发若干政策措施的实施意见 [Advice on the political measures to be implemented to promote Western development]. Retrieved January 17, 2013, from http://www.china.com.cn/chinese/zhuanti/xbkf5/798418.htm

General Office of the State Council of the People's Republic of China. (2002). 西部地区人才开发十年规划 [Ten-year plan for human capital development in the Western region of China]. Retrieved January 17, 2013, from http://www.china.com.cn/chinese/zhuanti/xbkf5/797861.htm

He, Y. P. (2007). 我国高校招生名额分配的省市差异及对策 [Difference in the distribution of new student quota across provinces and the corresponding strategy]. 宜宾学院学报 [*Journal of Yibin University*], *7*(9), 116–118.

Jia, Y. P. (2009). 我国高等教育资源地域分布的现状, 特点及成因 [Regional distribution of higher education resources: Current state, features and determinants]. 江苏高教 [*Jiangsu Higher Education*], (2), 48–50.

Li, S., & Xing, C. B. (2010). China's higher education expansion and its labour market consequences (Discussion Paper No. 4974). Bonn, Germany: IZA.

Liu, F. Z., Zhao, C. H., & Sun, Y. T. (2009). 我国高教资源区域分布差异与模式分析 [Analysis of regional distribution differences and patterns of higher education resources in China]. 大连理工大学学报 (社会科学版) [*Journal of Dalian University of Technology (Social Sciences)*], *30*(1), 56–61. doi: 10.3969/j.issn.1008-407X.2009.01.011

Liu, J. M. (2007). 扩招时期高等教育机会的地区差异研究 [Examination of regional disparities of higher education opportunity during the rapid expansion period]. 北京大学教育评论 [*Peking University Education Review*], *5*(4), 142–188. doi: 10.3969/j.issn.1671-9468.2007.04.013

National Development and Reform Commission, & Office of the Leading Group for Revitalizing Northeast China and Other Old Industrial Bases of the State Council. (2007). 东北地区振兴规划 [Plans of revitalising Northeast China]. Retrieved January 17, 2013, from http://chinaneast.xinhuanet.com/2007-08/20/content_10905015.htm

National Education Committee. (1995). 关于深化高等教育体制改革若干意见 [Advice on deepening the reform of the higher education system]. Retrieved January 17, 2013, from http://baike.baidu.com/view/4040977.htm

Office of Western Development of the State Council of the People's Republic of China. (2002). "十五"西部开发总体规划 [The 10th five-year general plan on Western development]. Retrieved January 17, 2013, from http://www.moc.gov.cn/zhuzhan/

jiaotongguihua/guojiaguihua/guojiaxiangguan_ZHGH/200709/t20070927_420871.html
Qiao, J. Z. (2007). 优质高等教育入学机会分布的区域差异 [Regional differentiations of entrance opportunity for high-quality higher education]. 北京师范大学学报(社会科学版) [*Journal of Beijing Normal University (Social Sciences)*], *199*, 23–28. doi: 10.3969/j.issn.1002-0209.2007.01.004

Shen, H. M. (2007a). Regional difference in distribution of China's colleges and universities and its impact on the equality in access to higher education. *Canadian Social Science*, *3*(1), 74–86.

Shen, H. M. (2007b). 高等教育升学机会地区间不平等的现状及其成因分析 [An analysis on regional inequality of higher education opportunities: Current state and its determinants]. 清华大学教育研究 [*Tsinghua Journal of Education*], *28*(3), 22–29.

Standing Committee of the National People's Congress. (1998). 中华人民共和国高等教育法 [Higher education law of People's Republic of China]. Retrieved January 17, 2013, from ttp://www.moe.edu.cn/publicfiles/business/htmlfiles/moe/moe_619/200407/1311.html

State Council of the People's Republic of China. (1994). 关于"中国教育改革和发展纲要"的实施意见 [Advice on practicing the guidelines for educational reform and development]. Retrieved January 17, 2013, from http://www.moe.gov.cn/publicfiles/business/htmlfiles/moe/moe_177/200407/2483.html

State Council of the People's Republic of China. (2000). 关于实施西部大开发的若干政策措施通知 [Notice on implementing political measures to promote Western development]. Retrieved January 21, 2013, from http://news.xinhuanet.com/politics/2006-04/13/content_4418526.htm

State Council of the People's Republic of China. (2004). 关于进一步推进西部大开发的若干意见 [Advice on progressing Western development]. Retrieved January 21, 2013, from http://www.china.com.cn/chinese/zhuanti/xbkf5/797286.htm

Xue, Y. H., & Xue, L. (2002). 试析我国高等教育的空间分布特点 [An exploratory analysis on the features of the spatial distribution of higher education]. 高等教育研究 [*Journal of Higher Education*], *23*(4), 44–49.

Zhang, Y. H., & Xing, L. X. (2008). 基于 GIS 对中国大陆高等教育区域差异分析 [Regional differences in higher education in mainland Chinese: An analysis based on GIS]. 现代教育科学 (高教研究) [*Modern Education Science (Higher Education Research)*], (2), 32–34.

Zhao, H. B., Liu, N. C., Liang, N., & Miao, Z. D. (2007). 我国高校的区域分布研究: 基于人口, GDP 的视角 [National research on the regional distribution of higher education: The aspect of population and GDP]. 高等教育研究 [*Journal of Higher Education*], *28*(1), 43–49.

Zhu, X. D., & Bei, Q. H. (2000). 关于高考分面前不平等问题的思考 [Thoughts on questions related to inequality through scores of higher education entrance exams]. 唐山师范学院学报 [*Journal of Tangshan Teachers College*], *22*(4), 61–64.

Appendix 1 Generalized Inequality Measures: Some Definitions

Supplementary to the definition of the weighted relative and the unweighted absolute Theil indices (equations (1) and (2) in Section 3), this Appendix provides definitions of the other inequality indices mentioned in Sections 3 and 4 of this paper (for a discussion see Bickenbach and Bode, 2008).

With the notation introduced in Section 3, the *generalised GE class of inequality measures* is defined as:

$$GE^{wr}(\alpha) = \frac{1}{\alpha^2 - \alpha}\left[\sum_{i=1}^{I} w_i \left(\frac{\frac{X_i}{\Pi_i}}{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}}\right)^{\alpha} - 1\right], \qquad \text{(A1)}$$

For the special case of $\prod_i = 1$ and $w_i = 1/I$ for all i we obtain the class of unweighted absolute GE measures:

$$GE^{ua}(\alpha) = \frac{1}{\alpha^2 - \alpha}\left[\frac{1}{I}\sum_{i=1}^{I}\left(\frac{X_i}{\frac{1}{I}\sum_{i=1}^{I} X_i}\right)^{\alpha} - 1\right]$$

$$= GE^{ua}(\alpha) = \frac{1}{\alpha^2 - \alpha}\left[\frac{1}{I}\sum_{i=1}^{I}\left(\frac{X_i}{\overline{X}}\right)^{\alpha} - 1\right], \qquad \text{(A2)}$$

The parameter α, which can take any real value, represents the GE-weight given to different observation-specific deviations from the mean. For lower values of α, the GE measure is more sensitive to changes at the lower tail of the distribution (of $X_i/\prod_i$), and for higher values of α, the measure is more sensitive to changes at the upper tail of the distribution (Cowell & Flachaire, 2007). For any α, the value of GE(α) is equal to zero if $X_i / \prod_i$ is the same for all i (perfect equality), otherwise it is strictly positive, with higher values of GE(α) representing higher levels of inequality (or concentration). For $\alpha > 0$, the upper bound of GE(α) is given by $UB_{GE(\alpha)} = (w_{\min}{}^{1-\alpha} - 1)/(\alpha^2 - \alpha)$, where $w_{\min}$ is the smallest weight. For $\alpha < 0$, GE(α) is unbounded from above.

The GE measures most frequently used in the literature are those with α being equal to 0, 1, and 2. For $\alpha = 2$, the weighted relative and unweighted absolute *GE(2)* indices can be directly obtained by inserting $\alpha = 2$ into (A1) and (A2), respectively. The unweighted absolute GE(2) index thus obtained is equal to the half of the squared coefficient of variation: $GE^{ua}(2) = CV^2/2$. For $\alpha = 1$ or 0, the term $1/(\alpha^2 - \alpha)$ is not defined and the corresponding GE indices have to be obtained by applying l'Hôpital's rule. For $\alpha = 1$, this gives the weighted relative *Theil* index, T^{wr}, and the unweighted absolute Theil index, T^{ua}, respectively (equations (1) and (2) in Section 3). For $\alpha = 0$, applying l'Hôpital's rule gives the weighted relative and unweighted absolute *GE(0)* indices (mean logarithmic deviations)

$$GE^{wr}(0) = \sum_{i=1}^{I} w_i \ln\left(\frac{\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}}{\frac{X_i}{\Pi_i}}\right) \text{ and } GE^{ua}(0) = \frac{1}{I}\sum_{i=1}^{I} \ln\left(\frac{\bar{X}}{X_i}\right), \text{respectively.}$$

The weighted relative and unweighted absolute *Gini* indices are given by (Bickenbach & Bode, 2008).

$$G^{wr} = \frac{1}{2\sum_{i=1}^{I} w_i \frac{X_i}{\Pi_i}} \sum_{i=1}^{I}\sum_{j=1}^{J} w_i w_j \left|\frac{X_i}{\Pi_i} - \frac{X_j}{\Pi_i}\right| \text{ and}$$

$$G^{ua} = \frac{1}{2\bar{X}}\frac{1}{I^2}\sum_{i=1}^{I}\sum_{j=1}^{J}\left|X_i - X_j\right|, \text{respectively.}$$

The unweighted absolute Gini index, which corresponds to half the normalised average absolute difference between all pairs of observations X_i ($i = 1 \ldots I$), can take values between 0 (perfect equality) and $1\text{-}1/I$ (maximal inequality, or complete concentration). Similarly, the weighted relative Gini index can take values between 0 and $1\text{-}w_{\min}$ (where $w_{\min}$ is the smallest weight).

Appendix 2 Selected Results for Alternative Inequality Measures

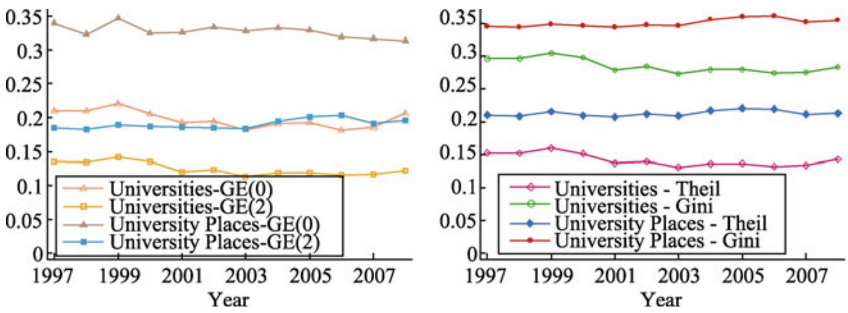


Fig. A1 Inequality in Distribution of Universities and University Places across Provinces: Comparison of Unweighted Absolute Inequality Measures

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京，中国: 人民教育出版社 [Beijing, China: People's Education Press].

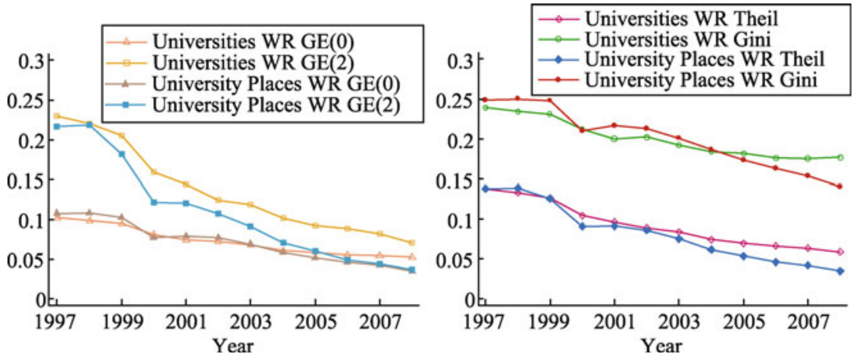


Fig. A2 Inequality in Distribution of Universities and University Places across Provinces: Comparison of Weighted Relative Inequality Measures

Note. Calculations based on 中国教育统计年鉴 [*Educational Statistics Yearbook of China*], by Ministry of Education of the People's Republic of China, 1998–2009. 北京, 中国: 人民教育出版社 [Beijing, China: People's Education Press]; 中国统计年鉴 [*China Statistical Yearbook*], by National Bureau of Statistics of China, 1998–2009. 北京, 中国: 中国统计出版社 [Beijing, China: China Statistics Press].