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Measuring the provincial supply of higher education institutions in China☆

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ABSTRACT

This paper proposes and estimates three novel higher education indices for 31 Chinese provinces: i) the Chinese Higher Education Density Index (*CHEDI*) to analyze the evolution of the quantitative distribution of higher education institutions (HEIs) in each province from 2001 to 2017, which is further decomposed into subgroups based on the type of college, i.e., four-year undergraduate colleges, two-year vocational colleges, and private institutions; ii) the Chinese Higher Education Quality Index (*CHEQI*) to examine the supply of higher education in terms of quality using a university ranking system; and iii) the Chinese Higher Education Index (*CHEI*), a composite indicator that incorporates both the quantity and quality dimensions of higher education institutions for each province, providing a weighted measure of the supply of higher education in China. The empirical findings indicate a significant and persistent heterogeneity in the supply of higher education between provinces. The indices identify which regions have been substantially rewarded by the higher education expansion of recent decades, going from an undersupply to a proportionate supply of higher education institutions. On the other hand, a significant share of regions still has a low supply in terms of either the quantity or quality of HEIs, or both.

1. Introduction

The world's largest economy and most populous nation is facing an important turning point as it transitions from a middle-income country towards a developed, high-income nation. Amidst declining economic growth rates and demographic dividends (Cai, 2010; Périsse & Séhier, 2019; Wenyao, Fen, & Yinmei, 2019), the People's Republic of China (PRC) has embarked on a series of structural transformations aimed at avoiding the middle income trap, including the "Made in China 2025" and "China Modernization 2035"

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programs (Chen, Chen, & Dondeti, 2020; Ministry of Education, 2018a). As China progresses to becoming an advanced and knowledge-based economy, its workforce must attain the necessary levels of human capital to meet the growing demand for high-skilled labor to drive productivity and innovation. In this regard, the PRC has made significant improvements in its educational development over the last decades, including the large-scale expansion of higher education institutions (HEIs) initiated in 1999. Nevertheless, the demand for higher education in China has always surpassed, and continues to exceed its supply. Furthermore, in spite of the considerable advances in expanding the supply of higher education, tertiary educational attainment levels and enrollment figures still fall significantly below those of higher income countries, and even below the upper-middle income average (World Bank, 2020). Given the range of the country's population and territory, it is essential to verify whether the multitude of educational policies and the founding of state-funded world-class universities in some regions could explain inequalities in terms of education and human development within China.

Motivated by the empirical context, this paper contributes to the research on higher education in China with the creation of three higher education indices for the 31 provinces, elaborated to reflect the quantity- and quality-related characteristics of China's higher education system. First, the Chinese Higher Education Density Index (*CHEDI*), which enables to analyze the evolution of the quantity of higher education institutions in each province relative to their population share. Additionally, the advantage of using the number of HEIs to study the supply of higher education is that the data can be further decomposed into subgroups based on the type of college, i.e., four-year undergraduate colleges, two-year vocational colleges, and private institutions. The *CHEDI* is estimated by constructing a unique dataset to make use of the supply of higher education instead of conventional measures of educational inputs and outputs. The panel dataset is compiled from the Ministry of Education Reports from 2001 to 2017, and to the authors' knowledge, no other study to date has used the number of higher education institutions by college type to analyze the supply and expansion of higher education for all provinces in China. The vast majority of previous works have measured higher education in China based on proxies for inputs, like investments; access and opportunity, such as enrollment figures; or educational outcomes, including attainment levels or years of schooling see, for instance, (see, for instance, Fleisher, Li, & Zhao, 2010; Gu, 2012; Li, Loyalka, Rozelle, & Wu, 2017; Zhou & Luo, 2018; Zhu, Peng, & Zhang, 2018; Wu, Yan, & Zhang, 2020). These measures, however, do not fully account for differences in college type and tend to conflate the supply, access to, and outcomes of tertiary education. In particular, the outcomes depend on how many people have access to higher education, which in turn, is determined by its provision, or supply. In other words, the number of HEIs is a key determinant of enrollment and attainment levels, and therefore constitutes the most suitable indicator for the supply of higher education in China. Since increases in the number of universities alone may positively affect economic growth and development (see, e.g., Valero & Reenen, 2019), the *CHEDI* for each province provides insights into regional imbalances, potentially driven by their disproportionately low or high supply of tertiary education. Second, the Chinese Higher Education Quality Index (*CHEQI*) is proposed to assess the supply of higher education in terms of quality, using a sophisticated university ranking system, the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU) published by ShanghaiRanking Consultancy. Specifically, the scores of all institutions listed in the annual Best Chinese Universities Ranking (BCUR) of ARWU are aggregated for the 31 provinces, and subsequently weighted by their respective population. The resulting *CHEQI* may be understood as an indicator of the quality of higher education institutions per million inhabitants in each province. This approach follows a substantial body of literature which argues that higher education should be analyzed both in terms of quantity and quality (see Benos & Zotou, 2014; Zhong, 2011, and references therein), and references therein. The *CHEQI* can be used by policymakers as a tool for assessing the competitiveness of each province's higher education and evaluate their agendas accordingly. Third, the Chinese Higher Education Index (*CHEI*) is a composite indicator that incorporates the quantity as well as quality of higher education institutions for each province, and thus provides a weighted estimate of the supply of higher education in China. The *CHEI* is complemented by a partial ranking analysis that addresses incomparabilities between provinces due to the quality and quantity dimensions of each. In particular, this non-aggregative quantitative approach based on the poset theory is applied for the first time in the higher education context, which allows to overcome the limitations of conventional aggregation methods.

The paper's findings suggest that despite the equalizing educational policies and the higher education expansion over the past decades, the distribution of the supply of tertiary education, both in terms of quantity and quality, remains unbalanced. While the densities of many provinces improved over the last 17 years, with several provinces going from an undersupply to a proportionate supply of HEIs, a third of them still have a low share of HEIs relative to their population. The *CHEDI* by college type further reveals that these improvements were mostly driven by increases in vocational colleges rather than undergraduate universities. Moreover, despite the massive surge of private HEIs, the market-oriented educational reforms have not particularly favored Central and Western regions. Regarding the *CHEQI*, there is a sizable gap between Beijing and the other 30 provinces in China: the capital not only has the highest density of HEIs, but many of them are also of high quality. In contrast, several Western and border provinces have a remarkably low *CHEQI*, pointing to an insufficiency, or undersupply, of better quality HEIs relative to their population. Finally, the composite *CHEI* confirms that Beijing, Tianjin, and Shanghai are the best-performing regions in terms of the overall supply of higher education institutions. On the other hand, either the quantity or quality indicator, or both, are relatively low in provinces with large populations, areas bordering other countries, and regions with large shares of ethnic minorities. The higher education indices enable a better understanding of the evolution of the supply of HEIs in each province and provide valuable insights for the PRC's current and future harmonizing educational policies.

The remainder of the paper proceeds as follows. Section 2 reviews the literature on the educational development policies and the higher education expansion in China. Section 3 describes the data. Section 4 details the methodological framework and presents the empirical findings. Section 5 offers alternative aggregations of the Chinese Higher Education Index, and finally, Section 6 provides a discussion of the results and concludes.

2. Higher education expansion in China

Over the last four decades, the PRC has experienced breakneck growth rates, lifting hundreds of millions out of poverty, and spearheading the nation to become the largest economy in the world measured by purchasing power parity. However, a large body of studies has advanced an academic debate of the several junctures that the PRC approaches in its transition from a middle- towards a high-income nation. According to the literature, its avoidance of a middle-income trap could be determined by technological development and innovation (Chen et al., 2020; Fu, Woo, & Hou, 2016; Liu, Serger, Tagscherer, & Chang, 2017; Pelzman, 2015; Zeng & Fang, 2014), income inequality (Li, 2017; Liu, Li, Wang, & Zhou, 2015), financial liberalization (Yao, 2015; Yiping, Qin, & Xun, 2014), political and structural adjustments (Feng, 2015; McKinney, 2018; Schweinberger, 2014; Shambaugh, 2018; Xu & Wang, 2017), and educational development (Wang, Li, Abbey, & Rozelle, 2018). The importance of education for economic growth and development has been widely recognized in the literature.[1] Similarly, a low, or undersupply of education is associated with slower development (Kosack & Tobin, 2015; Mayer-Foulkes, 2008). Despite the achievements made by China, its rapid development has been accompanied by increasing disparities between Chinese provinces (Glauben, Herzfeld, Rozelle, & Wang, 2012; Knight, Shi, & Quheng, 2009; Valerio Mendoza, 2018; Zhang, 2014). Thus, whether all parts of China will achieve adequate levels of educational attainment and human capital to meet its growing skills demand has been recently questioned (Cai, 2012; Fraumeni, He, Li, & Liu, 2019; Glazebrook & Song, 2013; Khor et al., 2016; Valerio Mendoza, Borsi, & Comim, 2021; Zhang, Li, Wang, & Fleisher, 2019; Zhang, Yi, Luo, Liu, & Rozelle, 2012). Since a more advanced economy requires a larger share of the workforce with higher education, as China continues to develop, the demand for tertiary education – understood as the number of students willing to enroll – is expected to increase. However, while this demand has been driven by the growing secondary education attainment levels, it is limited by the supply of higher education, which refers to the provision of higher education institutions, including physical buildings, faculty, admissions, and other resources.

Historically, the supply for higher education in China has always lagged behind the demand for it. After a period of stagnation that included the abolition of HEIs during the Cultural Revolution in 1966–1976, the subsequent economic reforms and opening up led to the revitalization of the nation's educational development reflected in the Nine-Year Compulsory Education Law in 1986. The educational reforms implemented in this legislation stimulated a rise in the construction, or reconstruction, of elementary and middle school buildings leading to an increased access to basic education, which manifested in a substantial surge in the respective enrollment rates. In turn, the larger number of middle school graduates fueled the demand for upper secondary education. However, the limited number of senior secondary schools created a bottleneck that was addressed with the construction of more high schools and the promotion of vocational upper secondary schools (Hu & Hibel, 2014; Valerio Mendoza, 2018). Similarly, the rise in secondary education completion rates prompted a soaring demand for higher education that was met with yet another bottleneck: the limited supply of higher education. Access to HEIs is determined by the National Higher Education Entrance Examination, or Gaokao, whose acceptance rates are an adequate proxy to reveal the insufficient supply of higher education (Qian & Smyth, 2011).[2] For instance, the acceptance rate of 21.55% for the Gaokao in 1990 suggests that 78.45% of those taking the exam were denied the opportunity of gaining access to higher education in China. This lack was addressed by the extraordinary large-scale expansion of HEIs initiated in 1999, which elevated the number of HEIs from 1034 in 1999 to 2740 in 2020. The higher education expansion produced an exceptional and unprecedented shock in enrollment rates (Knight, Deng, & Li, 2017), yet the Gaokao acceptance rates of 90.33% in 2020 suggest that the supply of higher education still falls below the demand.

The aforementioned educational development efforts have not been equally beneficial across all Chinese provinces. The reforms of the education system, initially characterized by financial and administrative decentralization, led to the uneven distribution of education resources (Zhang, Wu, & Zhu, 2020), regional educational inequalities, and disparities in educational opportunities (Li, Liu, Li, Fraumeni, & Zhang, 2014; Li, Whalley, & Xing, 2014; Luo, Guo, & Shi, 2018; Wu et al., 2020; Xiang, Stillwell, Burns, & Heppenstall, 2020; Yao, Wu, Su, & Wang, 2010). Specifically, coastal areas have achieved the largest enrollment and educational attainment levels, driven by the excess investment in the creation of primary, secondary, and tertiary education institutions in relation to non-coastal areas. At the turn of the century, the Central Government recognized the limitations of decentralization, and policies since then have prioritized education equality with a focus on providing access in disadvantaged areas (Xiang et al., 2020). Several reforms were aimed at improving compulsory education, including the Free Compulsory Education Law of 2006, the "National Medium and Long-Term Educational Reform and Development Plan Outline (2010-20)" of 2010, and further improvements of the funding guarantee system for urban and rural compulsory education in 2015 (Ministry of Education, 2016). Furthermore, the "High School Education Popularization Plan (2017-2020)" was implemented with the objective of promoting secondary educational attainment levels across the country (Ministry of Education, 2017a). And finally, the "Central and Western Higher Education Revitalization Plan" designated 10 billion yuan to construct 100 undergraduate universities in the central and western regions (Ministry of Education, 2016). These policies emphasized a highly centralized subsidization of education in inland areas (Xiang et al., 2020). As most provinces have approached full enrollment in compulsory education in recent years, provincial disparities in the corresponding enrollment rates have almost disappeared. Similarly, the equalizing efforts of the Central Government may lead to rising secondary education attainment levels across China, which in turn could translate into an even greater demand for higher education, suggesting that a continued expansion of its supply is necessary.

China's "Modernization Plan 2035" indicates that the nation should achieve human capital levels comparable to those of developed

[1] Benos and Zotou (2014) offer an exhaustive meta-regression analysis based on 57 studies on the effect of education on economic growth.

[2] Acceptance rates can be computed based on the number of applicants for the national college entrance examination and the number of accepted students, published by the Ministry of Education (2020b, 2021b).

countries within the next two decades (Ministry of Education, 2018a). In order to do so, China must continue to increase its supply of skilled labor since the share of its labor force with tertiary education still falls considerably short compared to developed economies, as illustrated in Table 1. The gap is huge; at 12.5%, China has between one-fourth and one-third of skilled labor relative to its labor force compared to USA, Germany, South Korea, Australia, and Japan. In order to bridge this gap, the country must increase its gross enrollment rates (GER), thereby augmenting the number of people that have the opportunity to access and achieve tertiary attainment. Table 1 also reveals that the selected OECD countries have between 29% and 130% higher GERs than China, suggesting that there is ample room for improvement in enrollment. Yet, in order to boost its GER, the supply of higher education should be further expanded. The magnitude of the supply gap with developed nations can be appreciated by comparing the number of HEIs per one million inhabitants in each country (see last column of Table 1). The United States has the highest ratio at 12.7 HEIs per million people, followed by South Korea (8.4), Japan (6.2), Australia (5.5), and Germany (4.8). Despite China having a staggering 2631 HEIs, once adjusted for its population, the figure of 1.9 pales in comparison to the selected countries'. Enhancing its supply of HEIs to increase enrollment rates is thus necessary to achieve a comparatively competitive labor force with a sufficiently large share with higher education.[3]

Even though research suggests that the increases in the number of universities alone positively affect economic growth and development (see, e.g., Dai, Cai, & Zhu, 2018; Valero & Reenen, 2019), in addition to expanding the quantity of HEIs, the PRC has also initiated programs aimed at improving the quality of its higher education. Most notable are Projects 211 and 985. The former refers to a strategic policy designed and implemented by the PRC in 1995 to improve the development of 116 HEIs that receive annual funding and national research grants from the Central Government, while the latter refers to the education program established by the Ministry of Education in 1998 to increase the number of world-class universities and world-famous high-level research universities by funding the infrastructure and research development of 39 first-tier universities (Wei & Johnstone, 2020; Zhang et al., 2020). The promotion of world-class universities resulted in the formation of an elite Chinese University "Ivy League" in 2009, known as the C9, composed of China's nine most prestigious universities, that was further complemented by the latest Double First-Class Universities Project in 2015, which aims to position the C9 universities among the best in the world (Wei & Johnstone, 2020).[4] Zhu et al. (2018) argue that "it is definitely necessary to upgrade China's higher education, in order to provide high-quality talents and high-level scientific research outputs for economic transformation and upgrade" (p. 2). They attribute the varying degrees of higher education development and economic growth to the number of universities from the 985 and 211 projects.

The results of these higher education projects have been the focus of recent research, where the quality of HEIs is often measured with the use of global university ranking systems, such as the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU), the Quacquarelli Symonds (QS) World University Rankings, the Times Higher Education (THE) World University Rankings, the Center for World University Rankings (CWUR), the Webometrics Ranking of World Universities, the Performance Ranking of Scientific Papers for World Universities (NTU Ranking), the CWTS Leiden Ranking, and others. The higher education quality projects, however, have exacerbated disparities in the financial burden for higher education between provinces. A few years before the expansion, the fiscal decentralization of HEIs placed the responsibility of financing higher education on local governments (State Council, 1993). Specifically, provincial, or municipal governments became mostly responsible for the development of HEIs under the purview of local governments, and the central government remained financially accountable for universities administered by the central ministries (Tang, 2020; Wu & Zhu, 2021).[5] The 211 and 985 projects thus predetermined that the selected universities would receive much higher funding per student from the central government fiscal budget than lower tier institutions which would have to rely disproportionately on local resources.[6] In other words, provinces with fewer centrally funded, or more locally governed HEIs would have a higher financial burden than other provinces. This problem was further heightened by reforms to the management system of universities in 1998 whereby 256 HEIs administered by the State Council departments were transferred to local governments (Ministry of Education, 2018b). The higher education expansion created a dramatic rise in college students, which in turn forced local governments to spend more in order to meet the teaching and research needs of HEIs. Provinces that could not keep up with the growth rate of university students experienced a decrease in their expenditure per student in provincially administered HEIs, which was considerably lower than in the 211/985 universities (Han & Xu, 2019; Wu & Zhu, 2021). The shortage of financial resources for higher education resulted in universities competing for limited amounts of provincial government funding. The most recently introduced Double First-Class Universities Project attempts to address these funding asymmetries by distributing funds from the central government budget to locally administrated HEIs in underdeveloped, or under-represented, provinces (Tang, 2020).

In addition, since public finance was not enough to satisfy the demand for higher education, the government encouraged private alternatives to public universities (Liu, 2020). Initially, most private universities in China were plagued with concerns about the

[3] The OECD average for the share of labor force with higher education in 2019 was 43.4%.

[4] The Double First-Class Project also aims to create 42 elite universities and 95 universities with First-Class disciplines by the middle of this century (Ministry of Education, 2017b; National Development and Reform Commission, 2017).

[5] Fiscal expenditures were not the only source of funding for colleges and universities. Other funding sources include tuition and fees, social donations, and income from commercial businesses held by universities (Wang, 2001). Despite these additional financing channels, fiscal funding from governments continues to be the most important funding source for HEIs especially since the share of tertiary education costs shared by governments is on the rise (Wu & Zhu, 2021).

[6] While central HEIs are at a higher hierarchy than local HEIs, there is further stratification within central and local HEIs. For example, out of the 111 central HEIs in 1998, 31 were considered as vice-ministerial level institutions, while the rest were classified at the department or bureau level. These hierarchies have persisted ever since. Similarly, only a few local HEIs are regarded as provincial/municipal key universities today, while the remainder are ordinary (Tang, 2020).

Table 1
Higher education stylized facts for selected countries.

Country	Share of labor force with tertiary attainment	Gross enrollment rate	Number of HEIs	Population	HEIs per million
China	12.5	49.1	2631	1386.4	1.9
USA	44.6	88.2	4131	325.0	12.7
Germany	38.9	70.2	399	82.7	4.8
S. Korea	45.4	94.3	430	51.4	8.4
Australia	48.2	113.1	135	24.6	5.5
Japan	49.5	63.2	780	126.8	6.2

Note: The share of labor force with tertiary attainment is presented for the year 2015 for all countries since this is the latest data available for China. Gross enrollment rates, number of higher education institutions (HEIs), and population figures correspond to the year 2017 for all countries except South Korea, which are from 2016. Population is in millions. Source: attainment figures are from the OECD and from the 1% population sample survey in 2015 for China. Enrollment and population data are from the World Bank. The number of HEIs are from the Ministry of Education (China), National Center for Education Statistics (USA), Deutscher Akademischer Austauschdienst (Germany), Korean Educational Development Institute (South Korea), Department of Education, Skills and Employment (Australia), and the Ministry of Education, Culture, Sports, Science and Technology (Japan).

quality of the education provided (Liu, 2020). In an effort to address these concerns, however, the State Council introduced new regulations in "The Outline of Education Reform and Development" and authorized private universities to award postgraduate level degrees (State Council, 2010). As a result, private universities flourished growing from only 31 in 1999 to 773 in 2020, constituting 28% of HEIs (Ministry of Education, 2020a). Nonetheless, the complexities in increasing the number of HEIs while meeting the demands of quality higher education in China are exemplified in the case of independent colleges. These hybrid institutions were privately managed colleges that were affiliated with a public university. They used the reputation of public universities while obtaining funds from the private sector (Wu & Li, 2021). Such public-private HEIs increased access to tertiary education at overpriced tuition fees but raised criticisms over their adherence to regulations regarding recruitment practices and financial management. Despite their potential for increasing enrollment without governmental investment, the Ministry of Education decided to restructure independent colleges over the past decade, forcing them to become entirely private or merge with vocational colleges (Ministry of Education, 2021a).[7]

The Central Government's educational policies and national strategies aimed at responding to challenges from academic competitiveness at a global level have been effective so far (Huang, 2015). Nevertheless, the resulting regional differences in the quality of HEIs have created disparities in earnings, and thus, returns to higher education based on the quantity of education alone can be misleading (Jia & Li, 2021; Zhong, 2011). Démurger, Hanushek, and Zhang (2019) show that such wage premia become even more pronounced the higher the quality. They estimate the returns to elite university education and find a substantial premium at job entry for graduating from a world-class Chinese university, especially in coastal provinces and economically more developed regions. However, it has been demonstrated that there can be a wage premium from elite colleges even if there is no improvement in test scores because of signaling or networking effects (Li, Meng, Shi, & Wu, 2012; Sekhri, 2020). On a related theme, Li et al. (2017) argue that the quality of college graduates has declined during the rapid higher education expansion of the last two decades. If university students are not learning enough during their tertiary education, China's labor force may not achieve the skills needed in an innovation-driven high income country (Loyalka et al., 2021). Since the PRC's goals of achieving a highly skilled labor force, vital to an advanced economy, rely on its ability to expand the supply of higher education and improve its quality, it is therefore important to analyze it both in terms of the quantity and quality, as proposed in this paper.

3. Data and descriptive statistics

3.1. Data

The higher education indices proposed in this paper rely both on a quantity and quality dimension. To determine the density of institutions in each Chinese province, higher education figures were taken from various issues of the List of National Colleges and Universities published by the Ministry of Education. Specifically, unique data for the total number of higher education institutions, four-year undergraduate colleges, two-year vocational colleges, and private institutions are compiled based on a series of publications each year, for a panel of 31 provinces of China spanning from 2001 to 2017. In addition, enrollment data are considered to provide further insights into the size of HEIs in each province. Province level enrollment figures come from the National Bureau of Statistics of China.

The quality measure is proxied using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU). In particular, all institutions listed in the annual Best Chinese Universities Ranking (BCUR) of ARWU are aggregated at the province level, and the overall score obtained by each is considered next, in order to construct the indicator of higher education quality. BCUR rankings have been published in the years 2015, 2017, 2018, and 2019, each based on data up to two years before publication. Since the key contribution of this paper is to offer an analytical framework to study jointly the quantity and quality of the supply of higher education

[7] In 2021 the restructuring of independent colleges has met resistance from various stakeholders in some Eastern provinces: https://www.globaltimes.cn/page/202106/1225775.shtml.

in China, this first attempt primarily makes use of the latest, 2019 ranking, which corresponds to 2017 higher education data. BCUR considers only four-year public and private universities and independent colleges that can grant bachelor's degrees recognized by the Ministry of Education of the PRC. The universities ranked in the BCUR 2019 include non-medical higher education institutions with a minimum undergraduate enrollment of 100 in 2017 and with a minimum publication of 100 papers indexed by Scopus (2013–2017). BCUR ranks these institutions according to their performance in four dimensions: teaching and learning, research, social service, and internationalization. Teaching and learning encompasses the quality of incoming students, education outcomes, and reputation (i.e., income from donations); research is based on the scale and quality of research, top research achievements, and top scholars; social service refers to the technology service and technology transfer; and finally, internationalization is captured by the international student ratio. For each of these measures, the best performing institution is assigned a score of 100, and all other institutions' scores are computed as a percentage of the top score. Overall scores are then obtained by taking the weighted average of the four dimensions considered. ARWU is regarded as one of the most influential and widely observed university rankings, and unlike other Chinese rankings using complicated methodological frameworks, BCUR offers a simple, comprehensive, reliable, and fully transparent university ranking that publishes overall scores as well as individual scores of each of the aforementioned indicators.[8]

Finally, the province-specific population data used throughout the study come from the National Bureau of Statistics of China. In the following two subsections a set of descriptive statistics are presented for the data employed for the quantity and quality measures proposed in this paper.

3.2. Descriptive statistics for the quantity of higher education

Table 2 reports summary statistics for the supply of higher education and population for the initial and final years of the panel. In particular, the table shows standard descriptive measures for the total number of higher education institutions, four-year undergraduate colleges, two-year vocational colleges, private institutions, enrollment, as well as the population in China. In addition, Table 2 presents the overall variation, i.e., growth, in the number of each type of college, enrollment, and the population from 2001 to 2017, together with the corresponding statistics. To complement these figures, Table 3 shows the number of HEIs in each province in 2001 and 2017 for total, four-year, two-year, and private colleges, in absolute terms as well as weighted by the province-specific population of each.

It is evident from the tables that China has experienced an unprecedented expansion of higher education over the past decades. The total number of higher education institutions has more than doubled, from 1081 to 2631 (Table 2), with the greatest increase in Jiangxi, exhibiting a growth of 222.58% from 2001 to 2017 (Table 3). In contrast, the total supply of higher education has varied the least in Beijing (55.93%), which could be explained by the fact that there were already 59 higher education institutions in the capital in 2001, whereas the panel average was slightly below 35 in the same year. In 2017 the greatest number of higher education institutions was located in Jiangsu (167), Guangdong (151), and Shandong (145), and another nine provinces hosted over 100 colleges each (Table 3). In contrast, Tibet (7), Qinghai (12), Ningxia (19), and Hainan (19) altogether accounted for only 2.17% of all higher education institutions in China.

Examining the different types of institutions separately reveals that – at the aggregate level – the number of four-year undergraduate colleges has been outpaced by the amount of two-year vocational schools during the period studied. Most importantly, the four-year college expansion has been primarily concentrated in the Eastern regions of China. While some provinces, including Hebei and Fujian, have increased their supply of four-year colleges by 177.27% and 236.36%, respectively, from 2001 to 2017, in other provinces such as Qinghai and Tibet the supply of four-year institutions remains low. By 2017, most of the four-year colleges were located in Jiangsu (77), followed by Hubei (68), Beijing (67), and Shandong (67), as shown in Table 3. In Qinghai, however, there were only three such colleges until 2016 when another one was established, and likewise, in Tibet there were only four four-year colleges in 2017, just as sixteen years before.

The higher education trends displayed in Table 2 and Table 3 are, on average, similar, still, somewhat more diverse for two-year vocational colleges in China. The substantial increase from 488 to 1388 institutions of this type was in part driven by a significant expansion in the coastal areas, such as Guangdong (314.39%), yet the greatest expansion was exhibited by Chongqing, with a growth of 471.43%, from seven to 40 two-year colleges between 2001 and 2017. Even so, most of the two-year colleges could be found in Jiangsu (90), Guangdong (87), and Henan (79) by the end of the sample period. Just as in the case of four-year higher education institutions, Qinghai and Tibet supply the lowest amount of two-year colleges in 2017, a total of eight and three, respectively.

Lastly, the expansion of private institutions has been the most pronounced. There were only 89 such higher education institutions in China in 2001, with no provinces having ten or more. By 2017, the overall growth of 724.72% since 2001 has led to the formation of 735 private colleges in China, of which the most, 49, are located in Jiangsu, while Tibet is the only province with no private higher education institutions at all. Although initially most private HEIs in China were vocational, by 2017, 57% (417) were undergraduate universities compared to 43% (318) vocational colleges.

It should be emphasized that while Tibet and Qinghai are the provinces with the fewest higher education institutions, they are also the smallest provinces in terms of population. Similarly, the three provinces with the greatest number of inhabitants, Guangdong, Shandong, and Henan, together with Jiangsu, have most of the HEIs. These resemblances are also reflected by the correlation coefficient of 0.79 between the total number of colleges and population. Hence, the number of higher education institutions – of each type –

[8] The reader is referred to ShanghaiRanking Consultancy's ARWU website for further details: http://www.shanghairanking.com.

Table 2
Descriptive statistics.

	2001					2017					Growth (2001–2017)				
	N	Mean	Std. dev.	Min	Max	N	Mean	Std. dev.	Min	Max	Overall	Mean	Std. dev.	Min	Max
Number of higher education institutions															
Total	1081	34.87	13.85	3	70	2631	84.87	41.55	7	167	143.39	149.06	47.70	55.93	222.58
Four-year	593	19.13	11.54	3	53	1243	40.10	20.76	4	77	109.61	113.86	56.28	0	236.36
Two-year	488	15.74	8.95	0	33	1388	44.77	23.25	3	90	184.43	207.26	93.75	66.67	471.43
Private	89	2.87	2.14	0	8	735	23.68	13.85	0	50	724.72	819.50	584.77	0	2350
Enrollment (total and provincial level)															
Enrollment	719.06	23.20	14.43	0.68	58.55	2753.61	88.83	55.38	3.56	201.53	282.95	318.10	125.12	76.20	610.73
Population (total and provincial level)															
Population	1267.83	40.90	26.46	2.63	95.55	1388.34	44.79	28.67	3.37	111.69	9.51	13.89	17.26	−5.76	56.98

Note: Summary statistics for higher education institutions refers to the total supply of higher education (Total), four-year undergraduate colleges (Four-year), two-year vocational colleges (Two-year), and private institutions (Private). Growth (2001–2017) refers to the percentage change in the number of higher education institutions, enrollment, and population from 2001 to 2017. Enrollment is in ten thousands and population is in millions. Source: List of National Colleges and Universities issued by the Ministry of Education and the National Bureau of Statistics of China.

Table 3
The supply of higher education institutions per province: 2001 and 2017.

2001		Total		Four-year		Two-year		Private	
Rank	Province	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million
1	Jiangsu	70	0.952	42	0.571	28	0.381	2	0.027
2	Liaoning	64	1.526	36	0.858	28	0.668	4	0.095
3	Beijing	59	4.266	53	3.832	6	0.434	3	0.217
4	Shandong	56	0.619	32	0.354	24	0.265	7	0.077
5	Hubei	54	0.904	30	0.502	24	0.402	4	0.067
6	Henan	52	0.544	21	0.220	31	0.324	4	0.042
7	Hunan	52	0.788	19	0.288	33	0.500	2	0.030
8	Guangdong	52	0.668	31	0.398	21	0.270	8	0.103
9	Hebei	51	0.761	22	0.328	29	0.433	4	0.060
10	Shaanxi	43	1.175	28	0.765	15	0.410	5	0.137
11	Sichuan	42	0.486	22	0.255	20	0.231	2	0.023
12	Heilongjiang	41	1.076	21	0.551	20	0.525	2	0.052
13	Anhui	41	0.648	20	0.316	21	0.332	5	0.079
14	Shanghai	37	2.292	23	1.425	14	0.867	7	0.434
15	Jilin	35	1.301	20	0.743	15	0.557	3	0.111
16	Zhejiang	35	0.759	20	0.434	15	0.325	2	0.043
17	Fujian	32	0.930	11	0.320	21	0.610	6	0.174
18	Jiangxi	31	0.741	16	0.382	15	0.358	3	0.072
19	Guangxi	30	0.627	13	0.272	17	0.355	1	0.021
20	Tianjin	29	2.888	18	1.793	11	1.096	2	0.199
21	Shanxi	26	0.795	13	0.397	13	0.397	1	0.031
22	Guizhou	25	0.658	9	0.237	16	0.421	1	0.026
23	Yunnan	24	0.560	13	0.303	11	0.257	2	0.047
24	Chongqing	21	0.678	14	0.452	7	0.226	4	0.129
25	Xinjiang	19	1.013	10	0.533	9	0.480	0	0.000
26	Inner Mongolia	18	0.757	10	0.421	8	0.337	1	0.042
27	Gansu	17	0.660	11	0.427	6	0.233	1	0.039
28	Hainan	8	1.005	4	0.503	4	0.503	2	0.251
29	Qinghai	7	1.338	4	0.765	3	0.574	0	0.000
30	Ningxia	7	1.243	4	0.710	3	0.533	1	0.178
31	Tibet	3	1.141	3	1.141	0	0.000	0	0.000

2017		Total		Four-year		Two-year		Private	
Rank	Province	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million
1	Jiangsu	167	2.080	77	0.959	90	1.121	49	0.610
2	Guangdong	151	1.352	64	0.573	87	0.779	50	0.448
3	Shandong	145	1.449	67	0.670	78	0.780	40	0.400
4	Henan	134	1.402	55	0.575	79	0.826	37	0.387
5	Hubei	129	2.186	68	1.152	61	1.034	42	0.712
6	Hunan	124	1.808	51	0.743	73	1.064	31	0.452
7	Hebei	121	1.609	61	0.811	60	0.798	36	0.479
8	Anhui	119	1.902	45	0.719	74	1.183	31	0.496
9	Liaoning	115	2.632	64	1.465	51	1.167	33	0.755
10	Sichuan	109	1.313	51	0.614	58	0.699	34	0.410
11	Zhejiang	107	1.891	59	1.043	48	0.849	34	0.601
12	Jiangxi	100	2.164	43	0.930	57	1.233	31	0.671
13	Shaanxi	93	2.425	55	1.434	38	0.991	30	0.782
14	Beijing	92	4.238	67	3.086	25	1.152	16	0.737
15	Fujian	89	2.276	37	0.946	52	1.330	36	0.920
16	Heilongjiang	81	2.138	39	1.029	42	1.108	17	0.449
17	Shanxi	80	2.161	33	0.891	47	1.270	15	0.405
18	Yunnan	77	1.604	32	0.667	45	0.937	20	0.417
19	Guangxi	74	1.515	36	0.737	38	0.778	24	0.491
20	Guizhou	70	1.955	29	0.810	41	1.145	15	0.419
21	Chongqing	65	2.114	25	0.813	40	1.301	26	0.846
22	Shanghai	64	2.647	38	1.572	26	1.075	19	0.786
23	Jilin	62	2.282	37	1.362	25	0.920	18	0.662
24	Tianjin	57	3.661	30	1.927	27	1.734	12	0.771
25	Inner Mongolia	53	2.096	17	0.672	36	1.423	10	0.395
26	Gansu	49	1.866	22	0.838	27	1.028	7	0.267
27	Xinjiang	47	1.922	18	0.736	29	1.186	9	0.368

(*continued on next page*)

Table 3 (*continued*)

2017		Total		Four-year		Two-year		Private	
Rank	Province	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million	Number of HEIs	HEIs per million
28	Ningxia	19	2.786	8	1.173	11	1.613	4	0.587
29	Hainan	19	2.052	7	0.756	12	1.296	8	0.864
30	Qinghai	12	2.007	4	0.669	8	1.338	1	0.167
31	Tibet	7	2.077	4	1.187	3	0.890	0	0.000

Note: The supply of higher education institutions (HEIs) per province refers to the total number of higher education institutions (Total), four-year undergraduate colleges (Four-year), two-year vocational colleges (Two-year), and private institutions (Private) for the 31 provinces in China in 2001 and 2017. Provinces are ranked in descending order according to the total number of higher education institutions. Source: authors' calculations using the List of National Colleges and Universities issued by the Ministry of Education and the National Bureau of Statistics of China.

per million inhabitants reported in Table 3 provides a more appropriate characterization of the distribution of the supply of higher education in China. As expected, this transformation benefits the provinces with smaller population, such as Ningxia or Tibet, whereas provinces with the largest number of inhabitants, including Guangdong, Shandong, and Henan, are penalized the most. In terms of international comparison, despite the large-scale expansion, the supply of HEIs per million inhabitants in China remains remarkably below that of the developed countries listed in Table 1. In fact, in 2017 only Beijing appears to be approaching levels similar to that of Germany with 4.2 HEIs per million, while the majority of the provinces have less than half of it, i.e., no more than 2.1 HEIs per million people (see Table 3).

Finally, the lower panel of Table 2 also shows that the population of China was steadily growing between 2001 and 2017, despite the one-child policy that was only abolished in 2015. Specifically, the total population increased by 9.51%, with Beijing and Tianjin exhibiting the largest growth, by 56.98% and 55.08%. Interestingly, in six out of 31 provinces the number of inhabitants decreased

Table 4
Average size of higher education institutions per province: 2017.

Rank	Province	Average size
1	Henan	14,960.45
2	Shandong	13,898.62
3	Sichuan	13,758.72
4	Guangdong	12,753.64
5	Guangxi	11,712.16
6	Shaanxi	11,498.92
7	Chongqing	11,490.77
8	Hubei	10,859.69
9	Jiangsu	10,586.23
10	Hebei	10,486.78
11	Jiangxi	10,483.00
12	Jilin	10,385.48
13	Hunan	10,267.74
14	Hainan	9763.16
15	Anhui	9642.02
16	Shanxi	9537.50
17	Gansu	9514.29
18	Zhejiang	9367.29
19	Yunnan	9167.53
20	Heilongjiang	9064.20
21	Tianjin	9029.82
22	Guizhou	8967.14
23	Liaoning	8530.43
24	Inner Mongolia	8454.72
25	Fujian	8438.20
26	Shanghai	8045.31
27	Xinjiang	7361.70
28	Beijing	6444.57
29	Ningxia	6373.68
30	Qinghai	5583.33
31	Tibet	5085.71
Mean		9726.22

Note: Average size refers to the average number of students enrolled in each higher education institution for the 31 provinces of China in 2017. Provinces are ranked in descending order. Source: authors' calculations using the List of National Colleges and Universities issued by the Ministry of Education and the National Bureau of Statistics of China.

throughout the sample period, with Guizhou suffering the largest decline in its population (−5.76%).

The evolution of the number of colleges clearly reflects the expanding supply of higher education in China over the past decades. Still, one may argue that the provincial differences in the number of institutions does not necessarily imply similar differences in the supply of higher education, since the size of colleges can vary between – and within – each province. Verifying this presumption is not as straightforward, since no statistical database offers information about the number of students enrolled in each Chinese higher education institution and year. Dividing the total number of higher education institutions by enrollment levels in every province, however, provides a plausible measure of the average size of colleges in each. The middle panel of Table 2 presents the summary statistics for provincial enrollment and Table 4 shows the average size of higher education institutions per province in 2017. In addition, Fig. 1 displays scatterplots of the total number of higher education institutions against enrollment and the average size of colleges per province in 2017, respectively. Enrollment on the national level has increased nearly fourfold during the observed period, with the most significant growth in Hainan (610.73%), one of the provinces with the fewest higher education institutions in 2001 (8). On the other extreme, Beijing is the province that not only exhibits the smallest increase in the number of colleges but also in terms of enrollment (76.20%). Shandong has the greatest number of students enrolled by 2017 (2015300), followed by Henan (2004700) and Guangdong (1925800), whereas, the province with the lowest enrollment levels throughout the entire sample period is Tibet (6800 in 2001 and 35,600 in 2017). In sum, the total number of colleges and enrollment levels move together remarkably closely, with a 94.7% correlation for the panel considered (also see Fig. 1/(a)). This correlation reduces to 79% after adjusting both figures by the population of each province (Fig. 1/(b)).

Turning to the size of higher education institutions, the data likewise indicate a high degree of correlation with the number of colleges (Fig. 1/(c)). With a few exceptions, provinces with greater number of colleges tend to have larger institutions on average as well (Table 4): seven out of the ten provinces with most of the higher education institutions (each over 100 colleges) also appear in the top ten – led by Henan – in terms of average size. Similarly, provinces with very few institutions, including Tibet, Qinghai, and Ningxia, have typically smaller colleges, according to their average size. The correlation coefficient between the total number of higher education institutions and the average size of colleges per province is 0.71. This relationship is higher once outliers including Beijing and Hainan are removed from the sample. However, after correcting for the provincial population, the average size appears to be smaller in areas with the highest concentration of HEIs per million inhabitants, and largest in those with the lowest concentration which are also the most populated regions (Table 1/(d)). Notable outliers include Qinghai and Tibet whose average size is the lowest even though having more than two HEIs per million.

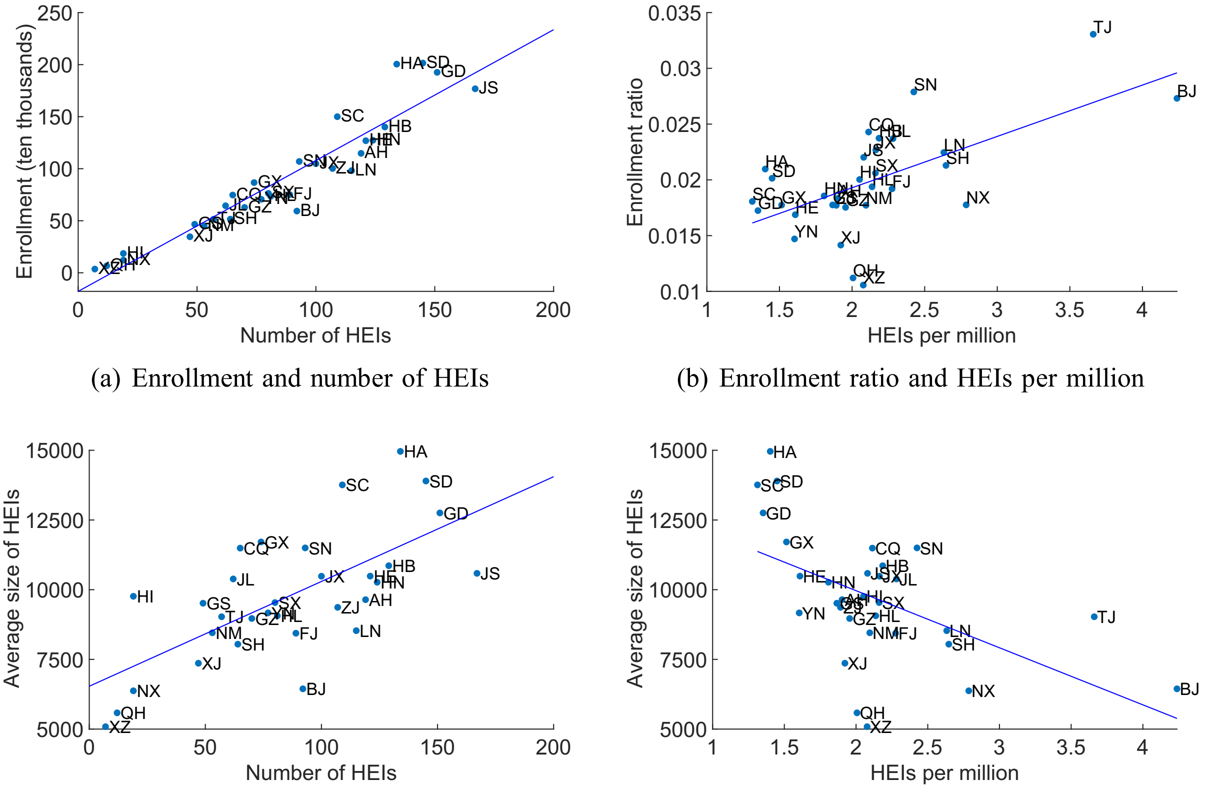
The provincial correlation between enrollment figures and the number of HEIs reveal comparable trends among the supply of, and access to, higher education. Even more, the strong relationship is explained by the bottleneck created by the limited supply of tertiary education discussed in Section 2. Specifically, the rise in secondary education completion rates was met with restricted access to higher education, and once the large-scale expansion of HEIs was initiated, it was immediately followed by increasing enrollment. Therefore, given the high demand, access to higher education has been, and continues to be, determined by its supply. Furthermore, the differences in the number of higher education institutions appear to be consistent with the disparities in the average size of colleges in each province. Finally, controlling for the number of inhabitants, in turn, suggests that population-weighted measures are the most suitable to analyze the supply of higher education in China.

3.3. Descriptive statistics for the quality of higher education

Table 5 reports the number of higher education institutions that have been included in the 2019 Best Chinese Universities Ranking of ARWU, aggregated at the province level. Provinces are shown in descending order according to the number of higher education institutions in each. While each province has at least one higher education institution in the 2019 ranking, the distribution of the 549 institutions listed is very unbalanced. The provinces leading the list are Beijing, Jiangsu, and Henan, which have 39, 37, and 30 – i.e., over one fifth – of the top 549 four-year colleges in 2017 in China. Conversely, in about one half of all provinces there are only 15 or less higher education institutions selected by ARWU, and moreover, in four provinces (Hainan, Qinghai, Ningxia, Tibet) there are only three or less such institutions, with Ningxia and Tibet having two and one, respectively.

One should note that there is a striking resemblance between the distribution of higher education institutions in the BCUR 2019 (Table 5) and the province-specific supply of four-year undergraduate institutions in 2017 in China (Table 3). In fact, the significantly positive correlation of 0.96 found between them lends support to the initial conjecture that the evolution of the number of higher education institutions in the 31 Chinese provinces is closely linked to the quality of higher education, and therefore, the accumulation of human capital in each. While the number of BCUR 2019 ranked universities and colleges per province may be indicative of the quality of higher education, there are substantial differences in the total scores obtained by all institutions listed. Tsinghua University (Beijing) is positioned first with a total score of 94.6, followed by three other C9 League universities that made it to the top four, namely, Peking University (Beijing), Zhejiang University (Zhejiang), and Shanghai Jiao Tong University (Shanghai).[9] All other institutions received an overall score below 70, with Hunan International Economics University (Hunan) closing the list with a score of 15.5. Given the disparities of such magnitude among the 549 higher education institutions in the BCUR 2019, both the number of

[9] The C9 League is an alliance of nine universities initiated by the Central Government through Project 985 in 2009 in order to promote world-class higher education in China, and comprises Tsinghua University (Beijing), Peking University (Beijing), Fudan University (Shanghai), Shanghai Jiao Tong University (Shanghai), University of Science and Technology of China (Anhui), Zhejiang University (Zhejiang), Nanjing University (Jiangsu), Xi'an Jiaotong University (Shaanxi), Harbin Institute of Technology (Heilongjiang, Shandong, Guangdong).



(a) Enrollment and number of HEIs

(b) Enrollment ratio and HEIs per million

(c) Average size and number of HEIs

(d) Average size and HEIs per million

Fig. 1. Enrollment and average size vs. the number of HEIs: 2017.
Note: Enrollment and enrollment ratio refer to the total number of students enrolled (ten thousands) and the number of enrolled per population, respectively, and average size is the average number of students enrolled in each higher education institution (HEI) for the 31 provinces of China in 2017. Source: authors' calculations using the List of National Colleges and Universities issued by the Ministry of Education and the National Bureau of Statistics of China. Province name abbreviations follow the ISO 3166-2 codes.

universities and colleges per province and the total scores obtained by each are incorporated in the formal analysis.

4. Methodology and results

This section first introduces the methodological framework to construct two disaggregate indicators as well as a composite measure based on the quantity and quality of higher education institutions in the 31 provinces of China. In what follows, the corresponding empirical results are presented and discussed in details.

4.1. Methodological framework

The quantity dimension of the provincial supply of higher education is defined here as the share of higher education institutions in relation to the share of population in each province i and period t:

$$QUANTITY_{i,t} = \frac{\frac{HEI_{i,t}}{HEI_{total,t}}}{\frac{POP_{i,t}}{POP_{total,t}}}, \tag{1}$$

where for each period t the share of higher education refers to the number of higher education institutions in province i ($HEI_{i,t}$), relative to the total number of higher education institutions in China ($HEI_{total,t}$), and the population share is calculated as the population of province i ($POP_{i,t}$) as a ratio of the total population of China ($POP_{total,t}$). Since the expression in Equation 1 provides a meaningful measure of the relative density of higher education institutions, it will be referred to as the Chinese Higher Education Density Index (*CHEDI*) hereafter. In terms of interpretation, for any province i and period t, values of $CHEDI_{i,t}$ above 1 suggest a proportionally high density of higher education institutions, whereas values below 1 represent provinces in which the share of institutions is low in relation to the province-specific share of population.

The quality indicator is determined using the scores obtained from the Chinese Universities Ranking provided by the Shanghai Jiao

Table 5
Number of higher education institutions per province in the 2019 Best Chinese Universities Ranking: 2017.

Rank	Province	Total
1	Beijing	39
2	Jiangsu	37
3	Henan	30
4	Hubei	29
4	Shandong	29
6	Guangdong	27
6	Liaoning	27
6	Shaanxi	27
6	Zhejiang	27
10	Hunan	26
11	Sichuan	23
12	Anhui	22
12	Shanghai	22
14	Hebei	21
15	Heilongjiang	16
15	Jilin	16
17	Jiangxi	15
18	Fujian	14
19	Tianjin	13
19	Chongqing	13
19	Yunnan	13
22	Guangxi	12
22	Shanxi	12
24	Gansu	10
25	Guizhou	8
26	Inner Mongolia	7
27	Xinjiang	6
28	Hainan	3
29	Ningxia	2
29	Qinghai	2
31	Tibet	1
Total (China)		549

Note: Total number of higher education institutions listed in the 2019 Best Chinese Universities Ranking (BCUR) for the 31 provinces of China (Total). The BCUR 2019 ranking refers to 2017 higher education data. Provinces are ranked in descending order. Source: Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

Tong Academic Ranking of World Universities (ARWU). In particular, the overall scores received by all higher education institutions listed in the Best Chinese Universities Ranking (BCUR) are aggregated for each province and year, divided by the province-specific population:

$$QUALITY_{i,t} = \frac{\sum_{j=1}^{J} SCORE_{j(i),t}}{POP_{i,t}}, \tag{2}$$

where $SCORE_{j(i),t}$ refers to the overall score obtained by university j in province i at period t. The expression in Eq. (2) may be understood as a measure of the quality of higher education per million inhabitants in China, and will be referred to as the Chinese Higher Education Quality Index (*CHEQI*). As an illustrative example, Beijing has a total of 39 higher education institutions listed in the BCUR 2019 (see Table 5), and summing up the scores obtained by each of them gives an aggregate score of 1524.4 for the year 2017. Dividing this score by the population of Beijing in the same period yields the $CHEQI_{i,t}$ of Beijing for 2017.

Finally, the composite measure proposed in this paper, the Chinese Higher Education Index (*CHEI*) for each province i and period t is computed as the arithmetic mean of the quantity and quality indicators described previously:

$$CHEI_{i,t} = \frac{CHEDI_{i,t} + CHEQI_{i,t}}{2}. \tag{3}$$

Calculating the $CHEI_{i,t}$ in Eq. (3) requires normalizing $CHEDI_{i,t}$ and $CHEQI_{i,t}$ so that all indicators are adjusted to a common scale with range [0,1] in order to produce a composite measure. Otherwise, it would not be appropriate to aggregate variables based on different scales. The process of normalization is widely used in the elaboration of composite indicators and has become well established with the popularization of the Human Development Index (Albo, Lanir, & Rafaeli, 2019; Aparicio & Kapelko, 2019; Barclay, Dixon-Woods, & Lyratzopoulos, 2019; Freudenberg, 2003; Yang, 2014). In technical terms, it consists in calculating a ratio between two distances, where the numerator is the distance between the value of a variable and its minimum value and the denominator is the distance between the maximum and the minimum value of the same variable.[10] Normalized values thus represent the relative performance of an indicator in relation to the maximum performance. Once both $CHEDI_{i,t}$ and $CHEQI_{i,t}$ are normalized, that is, have their values within the [0, 1] scale, a single composite indicator can be computed by taking the arithmetic average between them.[11]

The final measure *CHEI* represents a balanced view between two independent dimensions, the quantity and quality of the supply of higher education. If, on the one hand, this indicator represents a synthesis of how well regions are able to achieve a compromise between quantity and quality of higher education, on the other, it allows to decompose the measure and identify where are the main gaps. The intuition behind the *CHEI* is that by only looking at the expansion of places offered by the universities, one might miss the problem that this can be achieved at the cost of deteriorating the quality of higher education institutions. At the same time, by only considering the quality rankings of HEIs, one would ignore the important work of increasing the supply of university places, in particular in those areas that need the most. Within this context, the composite index proposed here puts forward a measure of the supply of higher education where both quantity and quality should equally matter. Furthermore, it allows any province to compensate a relatively lower performance in one dimension with a higher performance of the other.

It is important to reiterate that the quality dimension defined in this paper relies on data from the BCUR of ARWU, which only considers four-year universities and colleges in China. Thus, the quality measure for two-year vocational colleges is not available at this stage and should be further investigated. Given this limitation of the study, both the quality indicator of higher education institutions (*CHEQI*) and the Chinese Higher Education Index (*CHEI*) are only computed for four-year colleges. Nevertheless, when focusing on the supply of higher education in quantitative terms, the density measure of higher education (*CHEDI*) is determined for the total amount of higher education institutions, four-year undergraduate colleges, two-year vocational colleges, as well as private institutions, separately, to gain additional insights into the composition and evolution of higher education supply within, and between, different provinces in China.

4.2. Empirical results

Table 6 reports the Chinese Higher Education Density Index (*CHEDI*) results for 2017 for the total number of HEIs (Total), undergraduate universities (Four-year), vocational colleges (Two-year), and private HEIs (Private). Several findings deserve a mention. First, Beijing is the province with the highest density in 2017, closely followed by Tianjin. Their corresponding values of 2.236 and 1.932 indicate that their share of HEIs are about the double of their population ratio. In addition, another 18 regions have a Total *CHEDI* greater than 1, which implies that about two-thirds of all Chinese provinces' higher education share exceeds their population ratio. Furthermore, while Zhejiang, Gansu, and Hunan have values slightly below 1, yet there are seven regions that have a remarkably low supply of higher education given their share of inhabitants. Second, Table 6 reveals that the Total *CHEDI* of each province can be explained by the distribution of the different types of colleges. For instance, Beijing's top rank in Total *CHEDI* is driven by its disproportionately high share of undergraduate universities, reflected by its Four-year *CHEDI* (3.447). Meanwhile, the capital is only 13th and 8th in Two-year and Private densities, respectively. Despite significantly falling behind Beijing, Tianjin has the second highest undergraduate college density (2.152), and moreover, it is the only province where both four-year and two-year HEIs are very highly concentrated, relative to its population. This in turn explains its second position in terms of the Total *CHEDI*. Besides Beijing and Tianjin, another eight regions' higher education share exceeds their population ratio considering both types of colleges, whereas all other provinces either have a low density of one type that is counterbalanced by a high density of the other, or exhibit a relatively low supply of both types of institutions. For example, Inner Mongolia, Hainan, Qinghai, Guizhou, Xinjiang, and Anhui all have a Total *CHEDI* greater than 1, conformed by a relatively low supply of undergraduate universities compensated by a higher share of vocational colleges. Similarly, Shaanxi, Jilin, and Tibet have Total *CHEDI* values above 1, however, their overall education density is primarily determined by a greater concentration of four-year institutions that offsets their low densities of two-year colleges. In contrast, the seven, mostly populous provinces, including Shandong, Henan, Guangdong, and Sichuan, that have the lowest supply of HEIs suffer from low densities of both four-year and two-year colleges, relative to their large share of population, as well as in comparison to other regions. Finally, the Private *CHEDI* results show a more uneven distribution of private HEIs in 2017. While some provinces, including Fujian, Hainan, Chongqing, and Shanghai have a particularly large share of institutions of this type, others have very little to none.

The evolution and geographic patterns of the higher education density in China is displayed for each *CHEDI* in Figures 2 to 5.[12]

[10] The normalization method employed in this paper, also referred to as the Min-Max transformation, converts variables to a common scale of [0,1] as follows: for any province i and variable $j = CHEDI \mid CHEQI$ the formula is given by $\frac{x_{ij} - \min_i(x_{ij})}{\max_i(x_{ij}) - \min_i(x_{ij})}$, where x_{ij} is the original value of variable j for province i, and $\min_i(x_{ij})$ and $\max_i(x_{ij})$ refer to the minimum and maximum values of variable j across all provinces, respectively.

[11] Composite indicators can be created using different weighting and aggregation methods see, e.g., (see, e.g., Nardo et al., 2008). In this paper the arithmetic mean is preferred because it does not over-penalize low values of either dimension considered. Nevertheless, Section 5 complements the analysis with a robustness exercise using alternative aggregation methods.

[12] *CHEDI* results for each type of HEI encompassing the entire sample period from 2001 to 2017 are presented in Appendix A.

Table 6
Chinese Higher Education Density Index (*CHEDI*): 2017.

Rank	Province	Total	Four-year	Two-year	Private
1	Beijing	2.236	3.447 (1)	1.152 (13)	1.392 (8)
2	Tianjin	1.932	2.152 (2)	1.735 (1)	1.456 (6)
3	Ningxia	1.470	1.310 (8)	1.613 (2)	1.108 (14)
4	Shanghai	1.397	1.755 (3)	1.076 (17)	1.484 (4)
5	Liaoning	1.389	1.636 (4)	1.168 (12)	1.427 (7)
6	Shaanxi	1.280	1.602 (5)	0.991 (21)	1.478 (5)
7	Jilin	1.204	1.521 (6)	0.920 (23)	1.251 (11)
8	Fujian	1.201	1.057 (13)	1.330 (5)	1.739 (1)
9	Hubei	1.153	1.287 (9)	1.034 (19)	1.344 (9)
10	Jiangxi	1.142	1.039 (14)	1.234 (9)	1.267 (10)
11	Shanxi	1.140	0.996 (15)	1.270 (8)	0.765 (24)
12	Heilongjiang	1.128	1.150 (11)	1.109 (16)	0.847 (19)
13	Chongqing	1.115	0.908 (17)	1.301 (6)	1.597 (3)
14	Inner Mongolia	1.106	0.751 (25)	1.424 (3)	0.747 (26)
15	Jiangsu	1.098	1.071 (12)	1.121 (15)	1.153 (12)
16	Tibet	1.096	1.326 (7)	0.890 (24)	0 (31)
17	Hainan	1.083	0.844 (20)	1.296 (7)	1.632 (2)
18	Qinghai	1.059	0.747 (27)	1.338 (4)	0.316 (30)
19	Guizhou	1.032	0.905 (19)	1.146 (14)	0.791 (21)
20	Xinjiang	1.014	0.822 (23)	1.186 (10)	0.695 (28)
21	Anhui	1.004	0.804 (24)	1.183 (11)	0.936 (15)
22	Zhejiang	0.998	1.165 (10)	0.849 (25)	1.135 (13)
23	Gansu	0.985	0.936 (16)	1.028 (20)	0.504 (29)
24	Hunan	0.954	0.830 (21)	1.064 (18)	0.854 (18)
25	Hebei	0.849	0.906 (18)	0.798 (27)	0.904 (17)
26	Yunnan	0.846	0.744 (28)	0.938 (22)	0.787 (22)
27	Guangxi	0.799	0.823 (22)	0.778 (30)	0.928 (16)
28	Shandong	0.765	0.748 (26)	0.780 (28)	0.755 (25)
29	Henan	0.740	0.643 (30)	0.827 (26)	0.731 (27)
30	Guangdong	0.713	0.640 (31)	0.779 (29)	0.846 (20)
31	Sichuan	0.693	0.686 (29)	0.699 (31)	0.774 (23)

Note: Chinese Higher Education Density Index for all higher education institutions (Total), four-year undergraduate colleges (Four-year), two-year vocational colleges (Two-year), and private higher education institutions (Private) for 31 provinces for 2017. Provinces are ordered according to the Total *CHEDI*, while the rank within each subgroup is presented in parentheses next to the density values. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001–2018.

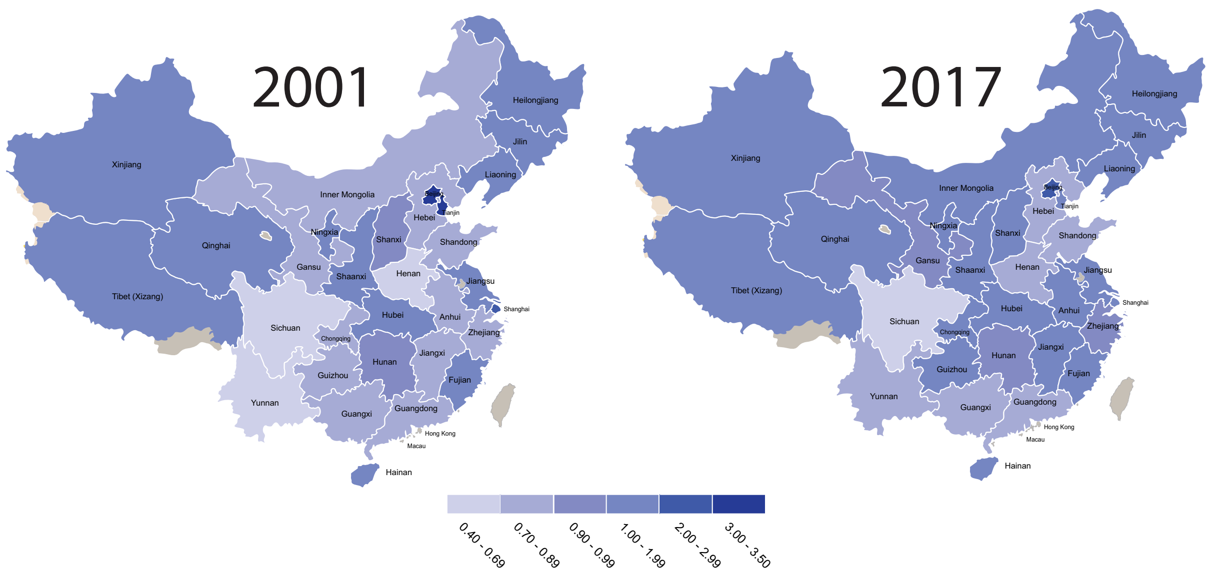


Fig. 2. Chinese Higher Education Density Index for 2001 and 2017: Total.
Note: Chinese Higher Education Density Index using the total supply of higher education institutions (Total). Sample: 31 Chinese provinces, 2001 and 2017. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001 and 2018.

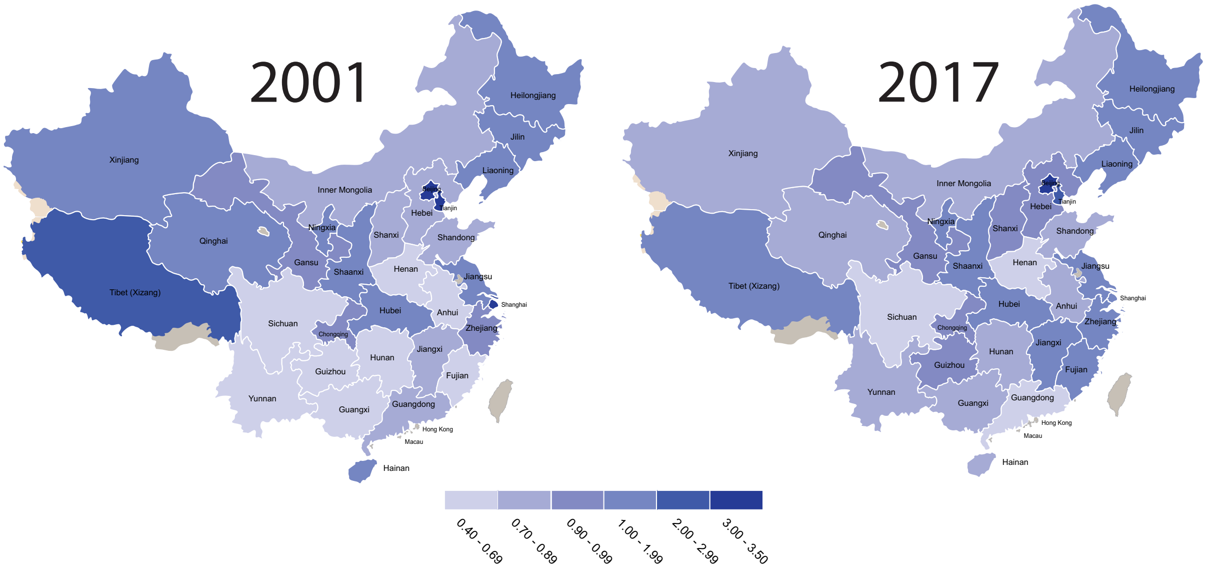


Fig. 3. Chinese Higher Education Density Index for 2001 and 2017: Four-year.
Note: Chinese Higher Education Density Index using four-year undergraduate colleges (Four-year). Sample: 31 Chinese provinces, 2001 and 2017. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001 and 2018.

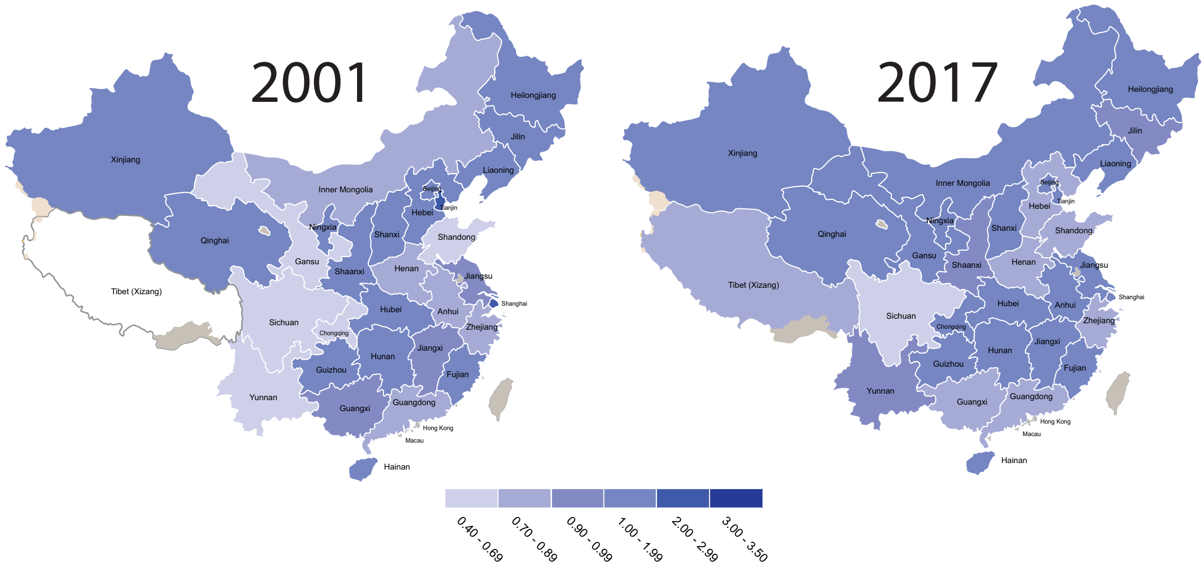


Fig. 4. Chinese Higher Education Density Index for 2001 and 2017: Two-year.
Note: Chinese Higher Education Density Index using two-year vocational colleges (Two-year). Sample: 31 Chinese provinces, 2001 and 2017. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001 and 2018.

Fig. 2 suggests that the higher education expansion of the last two decades has substantially improved the distribution of HEIs across regions. Of the 16 regions with Total *CHEDI* lower than 1 in 2001, 14 have increased their density measure, of which six provinces went from having an undersupply to a disproportionately high supply. Chongqing experienced the most considerable change in Total *CHEDI*, growing from 0.795 in 2001 to 1.115 in 2017 (40% increase). Likewise, Guizhou, Anhui, and Jiangxi increased their overall density by 34%, 32%, and 31%, respectively. Guangdong and Hebei are the only two regions with declining *CHEDI* over the years studied, which could be partly explained by their rapid population growth during the past two decades. The changes in the Four-year *CHEDI* are somewhat less pronounced (see Fig. 3). Even though 14 provinces managed to increase their *CHEDI* from 2001 to 2017, most of them

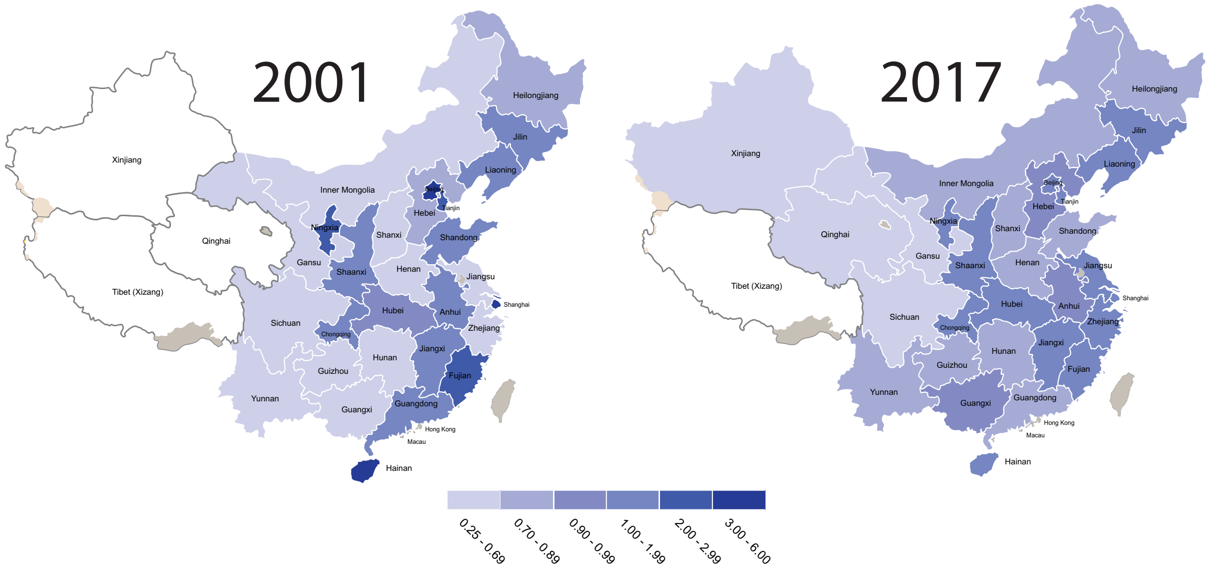


Fig. 5. Chinese Higher Education Density Index for 2001 and 2017: Private.
Note: Chinese Higher Education Density Index using private higher education institutions (Private). Sample: 31 Chinese provinces, 2001 and 2017. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001 and 2018.

Table 7
Chinese Higher Education Quality Index (*CHEQI*): 2017.

Rank	Province	*SCORE*	*CHEQI*
1	Beijing	1524.4	70.216
2	Shanghai	838.3	34.669
3	Tianjin	413.3	26.545
4	Shaanxi	779.4	20.323
5	Liaoning	759	17.372
6	Jilin	436.8	16.077
7	Hubei	931.6	15.784
8	Jiangsu	1232.1	15.346
9	Zhejiang	826.1	14.614
10	Heilongjiang	464.6	12.262
11	Chongqing	373.1	12.133
12	Hunan	712.3	10.383
13	Fujian	402.1	10.281
14	Gansu	252.1	9.600
15	Anhui	582.7	9.316
16	Shanxi	321.6	8.687
17	Qinghai	47.6	7.960
18	Jiangxi	364.8	7.893
19	Hainan	72.6	7.840
20	Sichuan	647.5	7.799
21	Shandong	774.4	7.739
22	Henan	720.9	7.542
23	Guangdong	833.7	7.464
24	Hebei	545	7.247
25	Ningxia	48.2	7.067
26	Inner Mongolia	164.5	6.505
27	Yunnan	309.6	6.449
28	Guangxi	309.2	6.330
29	Tibet	19.3	5.727
30	Xinjiang	133.8	5.472
31	Guizhou	172.6	4.821

Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores (*SCORE*) obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. Provinces are ranked in descending order according to the Chinese Higher Education Quality Index (*CHEQI*). Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

had a density either below or above 1 in 2001, which did not change by the end of the sample period. Zhejiang, Fujian, and Jiangxi are the only provinces that were able to switch from undersupply to an overproportioned supply of undergraduate colleges. Conversely, Hainan, Xinjiang, and Qinghai, went from having a proportionate supply in 2001 to an undersupply in 2017, relative to their population share. While maintaining *CHEDI* values above 1, Beijing, Tianjin, Shanghai, and Tibet have experienced a considerable reduction, suggesting that in these provinces the HEI expansion could not keep up either with the pace of their population growth or with the increasing HEI shares of other provinces. Interestingly, despite having one of the fewest four-year colleges in China, given its low population, Tibet still conserves a relatively high density of undergraduate universities by 2017 (1.326). Lastly, Fig. 3 reveals that Northern and Southern border provinces have low densities of four-year HEIs. The evolution of the density of two-year HEIs, illustrated in Fig. 4, indicates that the improvements in Total *CHEDI* are driven mainly by the rise in the number of vocational colleges. Among the 20 provinces with a Total *CHEDI* larger than 1 in 2017, 18 also have a Two-year *CHEDI* higher than 1. Even more, over half of the provinces have managed to increase their Two-year *CHEDI* since 2001. Most notably, Inner Mongolia, Gansu, Chongqing, and Tibet have all grown their vocational college densities by over 50%, with Chongqing witnessing a change of 122%. Finally, nearly all provinces have expanded their number of private HEIs since 2001 (see Fig. 5), with the most important changes in Guangxi and Jiangsu. These two provinces accumulated 24 and 49 private institutions in the final year of the panel, compared to only one and two, 16 years earlier, thus exhibiting an increase in their Private *CHEDI* by 212% and 198%, respectively. While Sichuan and Guizhou have also more than doubled their Private density, some areas have made little to no progress. At the extremes, Tibet remains the only region with no private college by 2017, reflected by its corresponding *CHEDI* of 0, whereas Fujian has the highest density of Private HEIs in the same year (1.741). Moreover, Fig. 5 also shows that the geographical distribution of private HEIs follows regional patterns of economic development since they are mostly concentrated towards Eastern and Central regions ever since the beginning of the sample. These regional disparities confirm that some provinces have still struggled to implement corresponding regulations for market-oriented higher education since the framework was published ten years ago, in 2010 (Liu, 2020). In sum, the *CHEDI* sheds light into geographical imbalances of higher education which has become a key challenge for the Chinese government in achieving equity in tertiary education (Gu, 2012).

The results for the Chinese Higher Education Quality Index (*CHEQI*) for four-year higher education institutions for 2017 are presented in Table 7. Moreover, to complement the analysis, Fig. 6 illustrates the corresponding province-specific distribution of higher education quality within China. The quality indicator (*CHEQI*) is computed using Equation 2, according to which the aggregate scores of higher education institutions listed in the BCUR 2019 for each province (*SCORE*) are divided by their population. It should be noted, however, that the resulting quality measure does not necessarily imply that provinces with low values have very few high quality institutions, but it rather indicates the quality of higher education institutions per million inhabitants in the 31 provinces of China. To provide a complete picture of the quality-based performance of each province in the absolute sense, i.e., unweighted by their province-specific population, the overall scores (*SCORE*) are also reported in Table 7. The regional patterns resemble some important similarities with the results obtained for the measure of the density of four-year HEIs. Specifically, besides the relatively high density of four-year colleges in Beijing, Tianjin, Shanghai, Liaoning, Shaanxi, and Jilin, these exact same provinces occupy the six highest positions according to the quality indicator of Chinese higher education institutions, in a slightly different order. Beijing is the first with the highest aggregate score among the 31 provinces (1524.4), and its position remains unchanged even after weighting the score by its population (*CHEQI*). It is important to emphasize that the Chinese capital does not only lead the list in terms of the *CHEQI*, but the second province, Shanghai, has a value of 34.669, which is less than half of the quality computed for Beijing (70.216). This result lends further support to the conjecture that Beijing is an outlier, clearly diverging above the rest of the provinces in 2017, with not only more, but also several much better four-year higher education institutions relative to its population size, according to the BCUR 2019 ranking (see Section 3.3). In addition, while Shanghai is the second province in terms of quality measured by the *CHEQI*, its overall score (838.3) falls behind that of Jiangsu (1232.1) and Hubei (931.6). This result suggests that while Jiangsu and Hubei may have more, well-ranked HEIs (also see Table 5), the quality of the supply of higher education is higher in Shanghai relative to its population. Similarly, other populous regions, such as Guangdong and Shandong, have the greatest number of HEIs in China, and therefore are also likely to have more HEIs in the BCUR 2019. This in turn explains their high overall scores (*SCORE*), still, however, weighted by the sizable population of each, their quality indices (*CHEQI*) are remarkably low (7.464 and 7.739, respectively). In contrast, Tianjin is the province with the fifth smallest number of inhabitants, yet it has 13 highly positioned four-year higher education institutions listed in the ranking, which puts it in third place according to its *CHEQI*.

Despite the quality findings displayed in Table 7 being largely consistent with the provincial density outcomes, however, a number of differences emerge. Most notably, Tibet exhibits a relatively high density of universities and four-year colleges given its low population, yet it is one of the three lowest ranked provinces in terms of *CHEQI*, together with Xinjiang, and Guizhou. On the contrary, provinces including Hunan, Anhui, and Qinghai rank much higher in quality with respect to their density of higher education institutions. The case of Qinghai is somewhat unexpected, since it is the province with the second lowest *SCORE* (47.6) after Tibet (19.4). Even so, weighted by its very small population it ranks as 17th, with a *CHEQI* of 7.960 right below the median. Finally, Fig. 6 illustrates that the quality of higher education in China is concentrated in Central, and especially, Eastern regions. At the same time, Western and border areas have a remarkably low supply of quality per million inhabitants. Some of the provinces with low *CHEQI*, such as Guangxi, Guizhou, Yunnan, and Tibet, are among the least developed regions in terms of per capita GDP and also have significant ethnic minority populations.

The *CHEQI* is computed using the 2019 Best Chinese Universities Ranking of the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU) published by ShanghaiRanking Consultancy. Besides being regarded as one of the most transparent and widely observed university rankings, it includes the largest number of Chinese universities by far. Specifically, a total of 549 institutions are listed in the BCUR 2019, whereas the majority of other academic rankings only include around 100 Chinese universities. Still, since

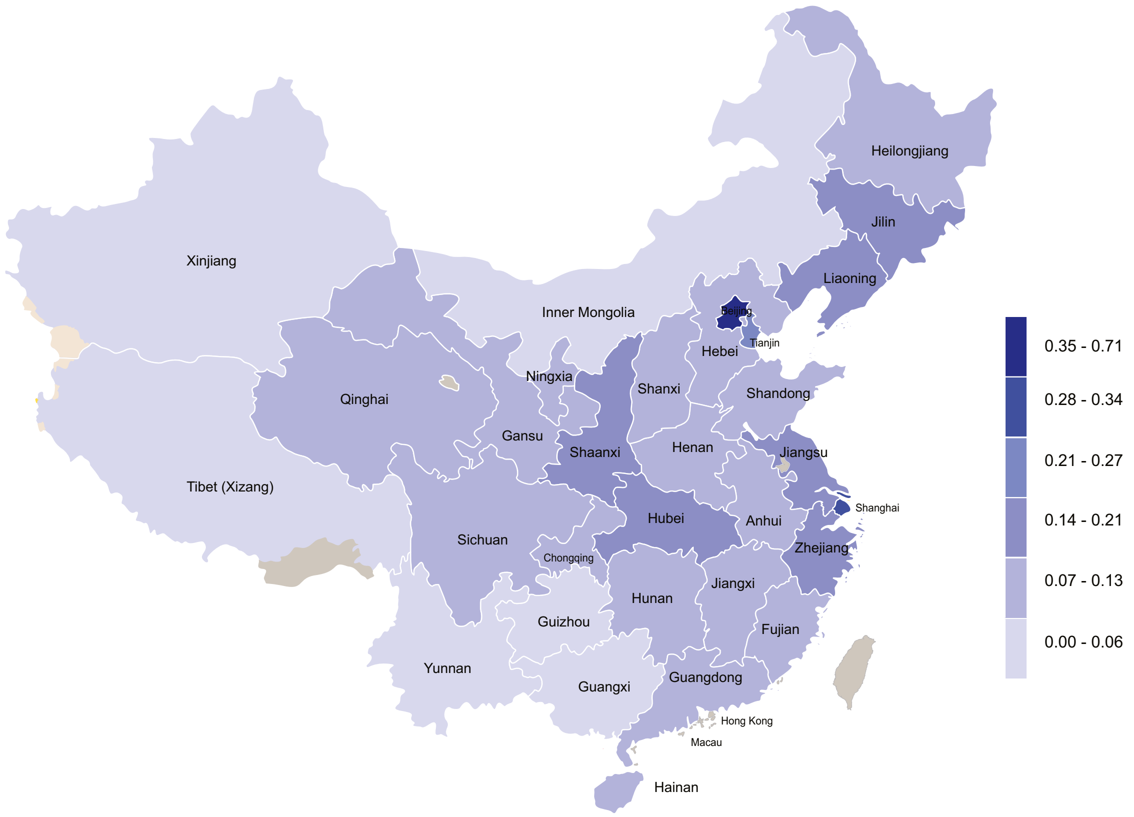


Fig. 6. Chinese Higher Education Quality Index (*CHEQI*): 2017.
Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

different rankings tend to prioritize different attributes, one would expect that the ordering of HEIs according to the quality measure may change depending on the ranking used. Hence, a robustness analysis is performed using three well known alternative academic rankings: the 2021 Times Higher Education China Subject Ratings (THE China 2021), the 2018–2019 Center for World University Rankings for China (CWUR 2018–19), and the 2019 QS Mainland China University Rankings (QS 2019). For each of these rankings, the *CHEQI* is computed as given by Equation 2, i.e., aggregating the scores of all HEIs across provinces and dividing the obtained values by the population of each.[13] The results are presented in Table 8 together with the *CHEQI* for the BCUR 2019. In addition, since the THE China 2021, the CWUR 2018–19, and the QS 2019 only include 90, 108, and 60 HEIs in their respective rankings, for the sake of better comparison the *CHEQI* is also computed considering only the first 100 universities (i.e., top 100) listed in the BCUR 2019 (second column of Table 8).[14] By and large, the quality measure appears to be very robust across the four rankings, even despite the differences in the methodology applied by each. In fact, with a handful of exceptions, provinces rank in a very similar order, both in quantitative and qualitative terms.[15] At the top, Beijing clearly stands out in all four rankings with a *CHEQI* about twice as much as that of the second province, Shanghai. At the lower end, the same nine provinces have no universities listed in any of the academic rankings studied (with the exception of the complete version of the BCUR 2019 that includes HEIs in each province). The high degree of coherence was somewhat unanticipated, since the different rankings give importance to different academic features. For instance, while the teaching and learning dimensions are apparent in all four rankings, technology and knowledge transfer related performance indicators are only considered in the BCUR and the THE China. The CWUR is the only academic ranking that does not include any measure of internationalization, however, it accounts for alumni employment, an indicator of top job placement of the university alumni. In addition, the THE China is the only ranking that measures performance based on subjects defined by China's Ministry of Education. Another remarkable difference is that the QS Mainland China University Rankings and the THE China Subject Ratings both

[13] The Times Higher Education China Subject Ratings calculates grades for each university within each subject using a grading system of A+ to C-. To compute the *CHEQI*, these grades were converted to equivalent numerical grades from 9 to 1, respectively.
[14] The 2019 QS Mainland China University Rankings lists a total of 99 universities, however, only 60 of them have scores provided.
[15] The correlation coefficients between the academic rankings considered fall between 0.97 and 0.99.

Table 8
Robustness of the Chinese Higher Education Quality Index (*CHEQI*) using alternative university rankings.

	BCUR 2019		BCUR 2019 (Top 100)		THE China 2021		CWUR 2018–19		QS 2019	
Rank	Province	*CHEQI*	Province	*CHEQI*	Province	*CHEQI*	Province	*CHEQI*	Province	*CHEQI*
1	Beijing	70.216	Beijing	48.775	Beijing	113.865	Beijing	68.006	Beijing	39.899
2	Shanghai	34.669	Shanghai	18.627	Shanghai	60.132	Shanghai	27.787	Shanghai	21.059
3	Tianjin	26.545	Jiangsu	7.844	Jiangsu	22.581	Jiangsu	14.448	Tianjin	8.638
4	Shaanxi	20.323	Tianjin	6.750	Tianjin	20.809	Tianjin	14.348	Shaanxi	4.089
5	Liaoning	17.372	Shaanxi	6.668	Shaanxi	16.949	Shaanxi	13.275	Jiangsu	4.076
6	Jilin	16.077	Hubei	5.427	Hubei	16.537	Chongqing	9.369	Hubei	3.694
7	Hubei	15.784	Zhejiang	3.942	Zhejiang	11.172	Zhejiang	6.394	Heilongjiang	2.919
8	Jiangsu	15.346	Jilin	3.202	Jilin	9.422	Hubei	6.264	Jilin	2.495
9	Zhejiang	14.603	Fujian	3.176	Fujian	9.103	Guangdong	5.849	Liaoning	1.932
10	Heilongjiang	12.262	Liaoning	2.987	Guangdong	8.900	Heilongjiang	5.767	Sichuan	1.718
11	Chongqing	12.133	Guangdong	2.773	Hunan	7.784	Jilin	5.410	Zhejiang	1.676
12	Hunan	10.383	Chongqing	2.686	Liaoning	7.530	Liaoning	5.006	Hunan	1.663
13	Fujian	10.281	Heilongjiang	2.555	Chongqing	7.122	Hunan	4.243	Fujian	1.583
14	Gansu	9.600	Sichuan	2.171	Sichuan	6.733	Fujian	3.771	Guangdong	1.561
15	Anhui	9.316	Anhui	2.144	Heilongjiang	5.252	Anhui	3.503	Anhui	1.524
16	Shanxi	8.687	Hunan	1.971	Anhui	3.821	Shandong	2.889	Gansu	1.314
17	Qinghai	7.960	Gansu	1.577	Shandong	3.558	Gansu	2.826	Chongqing	1.216
18	Jiangxi	7.893	Shandong	1.255	Guangxi	1.965	Sichuan	2.658	Shandong	0.931
19	Hainan	7.840	Hebei	0.000	Hebei	0.824	Shanxi	1.904	Hebei	0.000
20	Sichuan	7.799	Shanxi	0.000	Shanxi	0.000	Jiangxi	1.543	Shanxi	0.000
21	Shandong	7.739	Inner Mongolia	0.000	Inner Mongolia	0.000	Yunnan	1.456	Inner Mongolia	0.000
22	Henan	7.542	Jiangxi	0.000	Jiangxi	0.000	Guangxi	1.435	Jiangxi	0.000
23	Guangdong	7.464	Henan	0.000	Henan	0.000	Henan	0.762	Henan	0.000
24	Hebei	7.247	Guangxi	0.000	Hainan	0.000	Hebei	0.000	Guangxi	0.000
25	Ningxia	7.067	Hainan	0.000	Guizhou	0.000	Inner Mongolia	0.000	Hainan	0.000
26	Inner Mongolia	6.505	Guizhou	0.000	Yunnan	0.000	Hainan	0.000	Guizhou	0.000
27	Yunnan	6.449	Yunnan	0.000	Tibet	0.000	Guizhou	0.000	Yunnan	0.000
28	Guangxi	6.330	Tibet	0.000	Gansu	0.000	Tibet	0.000	Tibet	0.000
29	Tibet	5.727	Qinghai	0.000	Qinghai	0.000	Qinghai	0.000	Qinghai	0.000
30	Xinjiang	5.472	Ningxia	0.000	Ningxia	0.000	Ningxia	0.000	Ningxia	0.000
31	Guizhou	4.821	Xinjiang	0.000	Xinjiang	0.000	Xinjiang	0.000	Xinjiang	0.000

Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking (BCUR 2019), 2021 Times Higher Education China Subject Ratings (THE China 2021), 2018–2019 Center for World University Rankings for China (CWUR 2018–19), and the 2019 QS Mainland China University Rankings (QS 2019), for the 31 provinces of China. BCUR 2019 (Top 100) considers only the first 100 HEIs listed in the BCUR 2019. Provinces are ranked in descending order according to the Chinese Higher Education Quality Index (*CHEQI*). Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU), Times Higher Education China Subject Ratings, Center for World University Rankings (China), and the QS Mainland China University Rankings.

employ reputation surveys as well, whereas the BCUR and the CWUR only rely on hard data. Finally, the research dimension has a substantially greater weight in the BCUR and the CWUR (40% of the overall score) as compared with the QS Mainland China University Rankings (15% of the overall score). In the case of the THE China Subject Ratings the weight of research varies depending on the different subjects considered.

The results for the Chinese Higher Education Index (*CHEI*) reflect, by definition, much of the density and quality of higher education in China. Table 9 reports the *CHEI* computed for all 31 provinces for the year 2017, along with the normalized values of its quantity and quality dimensions, followed by the difference between the two components. Normalized values for *CHEDI* and *CHEQI* can be interpreted as the share of each relative to that of the province with the highest value, whereas the difference between them indicates quality and quantity gaps, i.e., higher or lower *CHEDI* than *CHEQI* within provinces, respectively. Not surprisingly, the province with the highest Index is Beijing, with a value of unity, given its leading position both in terms of quantity and quality. The capital is followed by Tianjin (0.435) and Shanghai (0.427), the only other provinces that have a *CHEI* above 0.3. Most noteworthy, the indicator value obtained by the second province, Tianjin, does not even reach one half of Beijing's score. This result is driven by Tianjin's low *CHEQI*, which is less than a third of Beijing's, despite having a very high *CHEDI*. These results reveal a significant imbalance between Tianjin's quantity and quality indices, precisely a quality gap, where the *CHEDI* exceeds the *CHEQI* by 0.47 (see last column of Table 9). Additionally, the landlocked province, Shaanxi, and two Northern coastal provinces, Liaoning and Jilin, have *CHEI* scores between 0.2 and 0.3, while the remaining 25 provinces' indices fall below 0.2. What is more, most provinces' normalized *CHEDI* values are higher than their *CHEQI*, suggesting that they are much farther away from the capital in terms of quality than quantity. At the lower bound, Henan and Guangdong are the two provinces with a *CHEI* closest to zero (0.021 and 0.020, respectively), primarily due to supplying the lowest number of four-year undergraduate colleges in China, relative to their province-specific share of population. In addition, while both of these provinces have numerous higher education institutions ranked in the BCUR 2019 (Table 5), their huge population also significantly reduces their quality indicator values per million inhabitants (Table 7).

The results presented here are suggestive of the evidence that Beijing performs significantly above all Chinese provinces – including Shanghai and Tianjin – in 2017 in terms of the supply of higher education. In other words, Beijing has a disproportionately large

Table 9
Chinese Higher Education Index and its components: 2017.

Rank	Province	*CHEI*	*CHEDI*	*CHEQI*	Difference
1	Beijing	1.000	1.000	1.000	0.000
2	Tianjin	0.435	0.803	0.332	0.471
3	Shanghai	0.427	0.456	0.456	0.000
4	Shaanxi	0.290	0.380	0.237	0.143
5	Liaoning	0.273	0.451	0.192	0.259
6	Jilin	0.243	0.331	0.172	0.159
7	Hubei	0.199	0.298	0.168	0.130
8	Zhejiang	0.168	0.198	0.150	0.048
9	Jiangsu	0.157	0.262	0.161	0.102
10	Heilongjiang	0.148	0.282	0.114	0.168
11	Ningxia	0.137	0.504	0.034	0.469
12	Tibet	0.129	0.261	0.014	0.247
13	Fujian	0.116	0.329	0.083	0.246
14	Chongqing	0.104	0.273	0.112	0.162
15	Jiangxi	0.095	0.291	0.047	0.244
16	Shanxi	0.093	0.290	0.059	0.231
17	Gansu	0.089	0.189	0.073	0.116
18	Hunan	0.076	0.169	0.085	0.084
19	Hebei	0.066	0.101	0.037	0.064
20	Anhui	0.063	0.202	0.069	0.133
21	Hainan	0.059	0.253	0.046	0.207
22	Guizhou	0.047	0.220	0.000	0.220
23	Guangxi	0.044	0.069	0.023	0.046
24	Qinghai	0.043	0.237	0.048	0.189
25	Shandong	0.042	0.047	0.045	0.002
26	Xinjiang	0.037	0.208	0.010	0.198
27	Inner Mongolia	0.033	0.268	0.026	0.242
28	Yunnan	0.031	0.099	0.025	0.074
29	Sichuan	0.031	0.000	0.046	−0.046
30	Henan	0.021	0.030	0.042	−0.011
31	Guangdong	0.020	0.013	0.040	−0.027

Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. The *CHEDI* and *CHEQI* are normalized to take values between 0 and 1. Difference refers to the gap between *CHEDI* and *CHEQI*. Provinces are ranked in descending order according to the Chinese Higher Education Index (*CHEI*). Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

amount of four-year higher education institutions relative to its province-specific population share, of which many are also of very high quality, according to the BCUR 2019 of ARWU. In contrast, Fig. 7 highlights that the *CHEI* is relatively low in populous regions (Guangdong, Henan, Shandong and Sichuan), those having boundaries with other countries (Guangxi, Yunnan, Xinjiang, and Inner Mongolia), and areas with large shares of ethnic minorities (Qinghai and Guizhou). Some of these provinces may face difficulties producing skilled labor, and could also face "brain drain" due to their limited supply of education, which in turn could hinder future economic growth and development.[16]

One may argue that the exceptional supply of higher education in Beijing makes it less comparable with the rest of the Chinese provinces and therefore it should be omitted from the analysis. Hence, as a complementary exercise, each indicator has been recalculated by removing Beijing from the sample (see Appendix C). While the key findings of the paper remain unchanged, excluding Beijing from the panel may offer a better grasp of the provincial distribution of higher education in China.

Although a formal analysis of how the disparities in the supply of higher education could affect the human capital accumulation, innovation, or economic development of each province is beyond the scope of this paper, the final part of this section aims to provide a better understanding of how the quality and quantity of HEIs are correlated with per capita GDP. Fig. 2 presents a set of scatterplots for each higher education indicator proposed in this paper against GDP per capita in 2017. The correlation coefficient of 0.61 which corresponds to Fig. 8/(a) suggests a reasonably strong relationship between per capita income and the Total density of HEIs. The relation is even stronger when considering the density of Four-year HEIs (0.64) displayed in Fig. 8/(b), in stark contrast with the density of Two-year colleges (0.20) shown in Fig. 8/(c). These results are indicative of the evidence that the distribution of two-year HEIs is not linked to the level of income of the 31 provinces in 2017, however, the density of four-year undergraduate universities

[16] Since BCUR rankings have already been published in 2015, 2017, and 2018 – that correspond to the years 2013, 2015, and 2016, respectively –, the *CHEQI* and *CHEI* have been computed for each available year, and the results are reported in Appendix B. The values obtained for both indicators are qualitatively and quantitatively similar to those of 2017, pointing to no significant improvement in the provincial distribution of the supply of higher education in China in recent years. These results, however, should be treated with caution, as the ranking methodology has constantly evolved since 2015, with additional ranking dimensions and criteria introduced in 2017 and 2018, and moreover, the 2019 edition of the BCUR for the first time only considers non-medical universities.

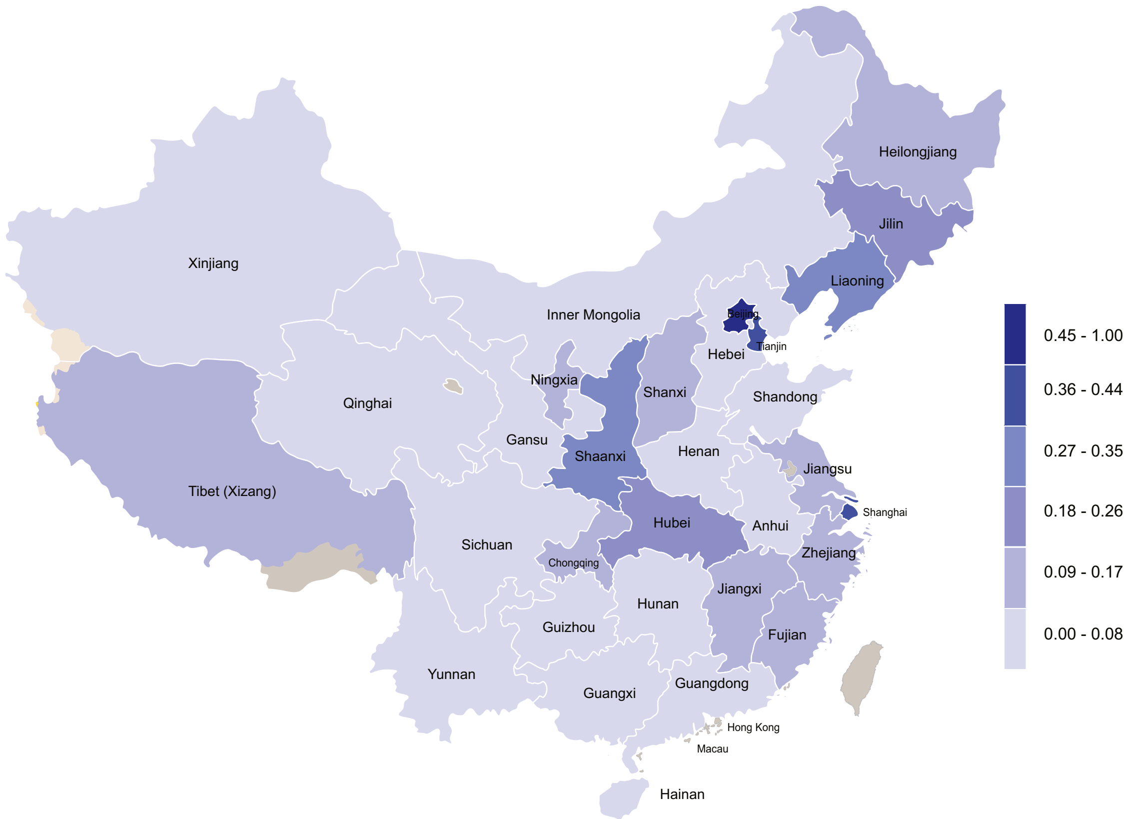


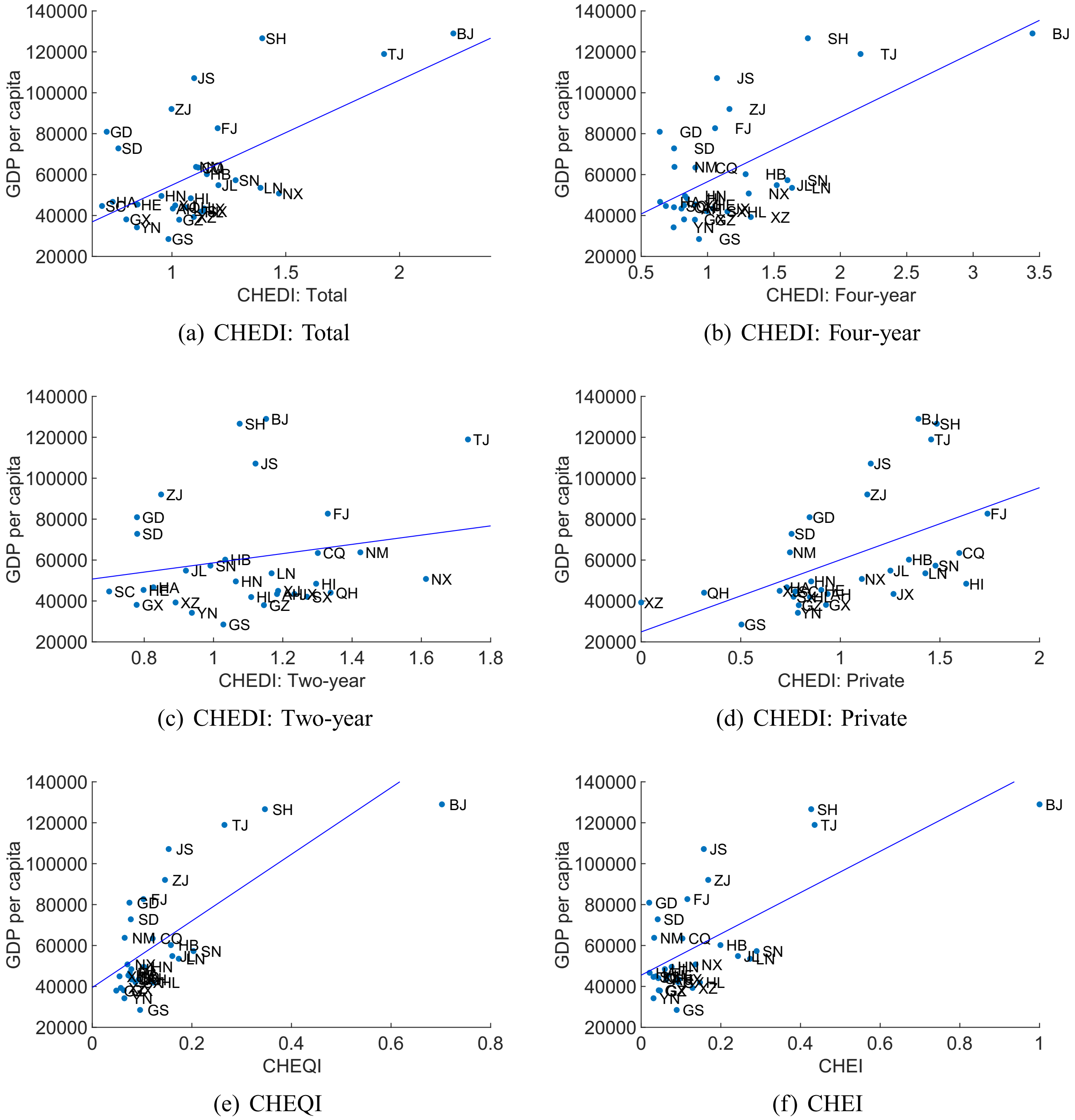
Fig. 7. Chinese Higher Education Index: 2017.
Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

appears to be higher in richer regions. In addition, the Private *CHEDI* is moderately correlated with GDP per capita (0.52), yet the relationship is much stronger when focusing on higher and lower income groups of provinces separately (see Fig. 8/(d)). The correlation is the highest between income and the *CHEQI* (0.74), which implies that the better quality HEIs are more likely to be concentrated in the wealthier areas (Fig. 8/(e)). Finally, the composite *CHEI* is also strongly correlated with GDP per capita (0.70), confirming the important association between the overall supply of higher education and economic development in China (Fig. 8/(f)).

5. Alternative aggregations of the Chinese Higher Education Index

The Chinese Higher Education Index (*CHEI*) presented in the previous section is defined as the arithmetic mean of its quantity- and quality-based components (Equation 3). By construction, there is a very high level of compensation among the different components when using the arithmetic aggregation method. Hence, for the sake of robustness, the composite measure of the supply of higher education has also been computed by taking the geometric average of the normalized values of *CHEDI* and *CHEQI* instead. The geometric mean demands a higher level of homogeneity among its different components, yet it may provide additional insights when the distinctiveness of the dimensions is to be emphasized. Regardless of these theoretical underpinnings, the results presented in Table 10 confirm that the *CHEI* is not sensitive to the choice of averaging, with only a few changes observed with respect to the original outcomes (Table 9). For instance, albeit Shanghai and Tianjin switching places, the top 10 provinces of the *CHEI* ranking remain unchanged. Most notably, Tibet and Guizhou are heavily penalized by the geometric mean, both provinces falling eight positions. In addition, since Guangdong is the last province in terms of *CHEDI* and Guizhou occupies the lowest position in *CHEQI*, the geometric averaging of their corresponding normalized values ranks both provinces last, with a *CHEI* equal to zero for each. Despite these differences, the fact that the results for both types of aggregations are very similar signal a high degree of homogeneity among the two components of the index.

A common argument against composite indicators is that they impose commensurability on distinct scales, which may be especially problematic when these scales – i.e., the dimensions of the *CHEI* –, are significantly different from each other. One possible solution to overcome this problem is the use of partial orderings, also known as poset analysis, that compares order relations and ordinal data in a



(a) CHEDI: Total (b) CHEDI: Four-year

(c) CHEDI: Two-year (d) CHEDI: Private

(e) CHEQI (f) CHEI

Fig. 8. *CHEDI*, *CHEQI*, and *CHEI* vs. GDP per capita: 2017.
Note: Chinese Higher Education Density Index (*CHEDI*), Chinese Higher Education Quality Index (*CHEQI*), Chinese Higher Education Index (*CHEI*), and GDP per capita (in Yuan) for the 31 provinces of China in 2017. Source: authors' calculations using the List of National Colleges and Universities issued by the Ministry of Education, the National Bureau of Statistics of China, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU). Province name abbreviations follow the ISO 3166-2 codes.

non-aggregative manner (Brüggemann & Patil, 2011). It contrasts attributes of any index without scaling or without introducing weighting schemes. It is metric-free and parametric free (Annoni & Brüggemann, 2009). In this sense, poset analysis adds value over alternative aggregation methods because it shows precisely where one can find incomparabilities when putting together different dimensions of composite measures. Whereas the disputes between arithmetic and geometric averages focus on the relevance of distinct rates of conversion of one outcome in terms of another, poset analysis emphasizes where we can find conflicting components of

Table 10
Chinese Higher Education Index using the geometric mean: 2017.

Rank	Province	*CHEI*
1	Beijing	1
2	Shanghai	0.426
3	Tianjin	0.423
4	Shaanxi	0.285
5	Liaoning	0.261
6	Jilin	0.232
7	Hubei	0.197
8	Zhejiang	0.167
9	Jiangsu	0.157
10	Heilongjiang	0.144
11	Fujian	0.111
12	Chongqing	0.103
13	Ningxia	0.091
14	Gansu	0.088
15	Shanxi	0.087
16	Jiangxi	0.082
17	Hunan	0.076
18	Anhui	0.063
19	Hebei	0.059
20	Tibet	0.058
21	Hainan	0.058
22	Qinghai	0.043
23	Shandong	0.041
24	Guangxi	0.039
25	Inner Mongolia	0.032
26	Yunnan	0.030
27	Sichuan	0.027
28	Xinjiang	0.025
29	Henan	0.006
30	Guangdong	0
31	Guizhou	0

Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. Provinces are ranked in descending order. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

composite indices and how they are distributed along the ordering of distinctive elements.[17]

Following Fattore, Maggino, and Colombo (2012) and Fattore (2016), it is possible to characterize a partially ordered set $P = (X, \leq)$ as a set X that follows a binary relation $\leq$ characterized by the properties of reflexivity, antisymmetry, and transitivity. Specifically, set X here includes $i = 1, 2, \ldots, 31$ elements x^i, where each element represents a vector of the quantity and quality dimensions for the 31 provinces of China. For instance, $x^i = (x_{CHEDI}{}^i, x_{CHEQI}{}^i)$ is a vector that considers both the *CHEDI* and *CHEQI* of province i. When provinces are comparable, that is, when for any two provinces i and j either $x^i \leq x^j$ or $x^j \leq x^i$, a *chain* is defined. On the other hand, if any two elements are incomparable, then an *antichain* is formed. This is the case when provinces cannot be ranked because either one ranks higher in the criterion of quantity whereas another is higher in the quality dimension, or vice versa.

Partial orderings can be illustrated by a Hasse diagram composed of a series of chains and antichains, where the number of elements of the longest chain and largest antichain define the *height* and *width* of the poset, respectively. In terms of visual representation, provinces are organized both vertically and horizontally, and sequences of orderings in the Hasse diagram are displayed such that for any two provinces i and j, if $x^i \leq x^j$, then province j is placed above province i and a line is inserted, linking the two provinces. Additionally, it could also happen that province j is above province i but they are not connected, suggesting that they are incomparable to each other, yet comparable within the diagram by the properties that characterize the poset. In other words, chains are represented by lines that link different provinces, and when provinces are not connected it means that they do not belong to the same chain and that they are not directly comparable, even if one of them is at a higher level of the Hasse diagram. Antichains are defined by such incomparabilities among the attributes of some provinces in the sample.

Fig. 9 presents the Hasse diagram of the poset analysis on *CHEDI* and *CHEQI* for the 31 provinces of China. In contrast to the 31 and 30 positions obtained using the arithmetic and geometric aggregations, the poset analysis yields a total of 14 levels of rankings according to the incomparabilities among the quantity and quality indicators of each province. Consistent with the findings of the

[17] For a detailed description of the methodology, also see Fattore (2016), and references therein.

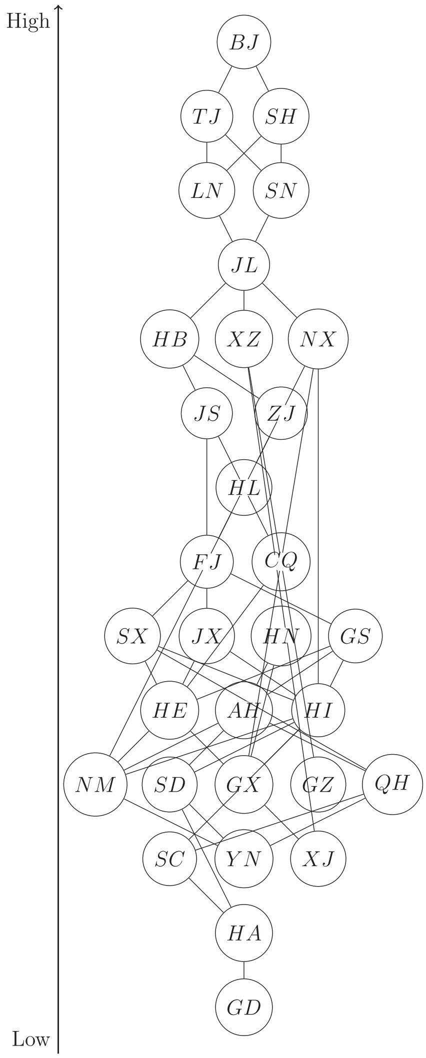


Fig. 9. Hasse diagram of poset analysis on *CHEDI* and *CHEQI*: 2017.
Note: Poset analysis based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for the 31 provinces of China. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU). Province name abbreviations follow the ISO 3166-2 codes.

previous aggregations, at the very top there is a clear leadership of Beijing compared to all other provinces. Tianjin and Shanghai are both linked to the capital and occupy the second level of the poset. Similar chains are formed between other provinces as well, whenever the vector of one has dominance over the other. It is interesting to note that as much as both Tianjin and Shanghai have lower quality and density indices in comparison with those of Beijing, when compared between themselves, no conclusive result can be achieved, thus, resulting in an antichain. This is due to the fact that Tianjin's *CHEDI* is higher than Shanghai's ($2.152 > 1.755$) but Shanghai's *CHEQI* is higher than Tianjin's ($0.347 > 0.265$). Even though the differences between the arithmetic and geometric averaging are minor, it should be noted once again that the former puts Tianjin ahead of Shanghai, whereas the latter favors Shanghai. Another example of such discrepancies is the ranking of Tibet. This low-populated, primarily rural, western province performs remarkably well in terms of *CHEDI*, however, with only one higher education institution listed in the BCUR 2019 its *CHEQI* is among the lowest. These differences are undoubtedly compensated among the two attributes when considering the arithmetic mean, while the geometric aggregation assigns a greater importance to the low value of the quality indicator of Tibet. In contrast, the poset analysis reveals that only Beijing, Tianjin, Shanghai, Liaoning, Shaanxi, and Jilin rank higher than Tibet, outperforming it both in terms of quality and quantity. Besides Guizhou and Xinjiang, however, no other provinces are directly comparable with it. As displayed in Fig. 9, the highest level of incomparabilities of this type is found at the lower-middle, with Inner Mongolia, Shandong, Guangxi, Guizhou, and Qinghai forming the largest antichain in the Hasse diagram that gives the width of the poset as five. Further incomparabilities yielding smaller antichains are distributed over all poset, suggesting a reasonable order of discrimination in a poset with 14 levels. Finally, other clear relations of order can be found at the very bottom, with Guangdong occupying the lowest level of the ranking, followed by Henan.

While partial rankings with two dimensions are relatively simple, they do sufficiently well in highlighting the complexities of aggregating different dimensions of a composite index. In particular, at a total of nine levels it is not possible to decide which province ranks higher than the other because of their conflicting quantity and quality attributes, yet such incomparabilities are fully overlooked when using arithmetic and geometric averaging methods.

6. Discussion and concluding remarks

This paper offers a novel empirical framework to analyze the supply of higher education at the province level in China. Specifically, based on a unique dataset compiled for Chinese higher education institutions, three indices are estimated to offer a more comprehensive perspective of quantity and quality dimensions that avoids conflating the supply of higher education with its inputs, access, and outcomes: the Chinese Higher Education Density Index (*CHEDI*) and Chinese Higher Education Quality Index (*CHEQI*) reflect the quantity and quality of higher education institutions in each province relative to their population, whereas the Chinese Higher Education Index (*CHEI*) incorporates both, thereby providing a balanced composite measure of the supply of higher education across the country. In addition, a poset analysis based on partial orderings is performed to identify incomparabilities between provinces due to the quality and quantity attributes of each.

The results show that in spite of the PRC's equalizing educational policies over the past decades, the large-scale expansion of higher education institutions since 1999 has rewarded some regions more than others. The supply of higher education is disproportionately greater in three of the provincial-level municipalities of China, with Tianjin, Shanghai, and especially Beijing having excessively high concentrations of HEIs and high-quality universities per million inhabitants, compared to the other provinces. On the other hand, the *CHEDI* provides a straightforward measure for which provinces have an undersupply of HEIs relative to their populations. Still, most areas managed to improve their densities over the 17 years examined, even though many of the gains were due to the rise of vocational colleges rather than undergraduate universities. The share of two-year colleges in China of 53% in 2017 may seem particularly high compared to other countries' such as the 36% of the United States. Given the rising demand for tertiary education, however, promoting vocational HEIs to increase the supply of higher education seems reasonable because it provides working skills that could directly increase productivity. In fact, Vu, Hammes, and Im (2012) find that vocational education appears to have a larger effect on economic growth than four-year university education. In addition, private universities can complement public efforts to increase the supply of higher education. Recent empirical evidence shows that some private colleges have resulted from large corporations needing to produce their skilled workforce faced with a severe shortage of employees (Liu, 2020). Nevertheless, the evolution of the density index for private HEIs reveals that many regions have been slow to promote private universities over the past decades. The estimates also highlight provincial differences in the quality per million people pointing to the challenge of increasing the number of HEIs while maintaining the demands for quality higher education in China. The financial allocation mechanisms resulting from decentralization efforts and the world-class university projects have placed a higher fiscal burden on local governments with fewer national key universities. Furthermore, market-oriented solutions have encountered similar difficulties providing high quality private HEIs and independent colleges. Therefore, some provinces with a relatively high density may have a low quality indicator, and vice-versa. In other words, the results suggest that key quantity-quality imbalances are present within Chinese regions.

Indeed, apart from Beijing, Shanghai and Shandong, all provinces have important divergences between their higher education quality and quantity measures. Some regions including Tianjin, Ningxia, Liaoning, Tibet, and Fujian display significant quality gaps, i. e., a considerably lower *CHEQI* than *CHEDI*. In contrast, Henan, Guangdong, and Sichuan are the only provinces that present quantity gaps i.e., a higher *CHEQI* than *CHEDI*. In analytical terms, this means that educational policies can improve the supply of higher education in China by tailoring policies according to the gaps identified in this paper. Targeted educational interventions are better than general claims about the importance of quantity and quality of education to reduce spatial inequalities (Zhong, 2011). This result is not simply about focusing investment on Central, Western, and border provinces but mostly about more attention to their particular higher-education needs. For instance, provinces that still have an undersupply of HEIs relative to their population might prioritize quantity over quality, since there is no guarantee that graduates from elite colleges will translate into more productive workers (Li et al., 2017; Loyalka et al., 2021; Sekhri, 2020), whereas increases in the number of HEIs alone may boost human capital levels and the economy as suggested by Valero and Reenen (2019). Likewise, those regions with a proportionate density of HEIs but a quality gap, might decide to prioritize quality over quantity.

The tremendous expansion of higher education across the globe during the 20th century revealed that nations faced numerous difficulties providing an equal quality of tertiary education to the increasing number of students (Devereux & Fan, 2011; Gebel & Pfeiffer, 2010; Oppedisano, 2011). Such a trade-off between the quantity and quality of education is unavoidable, even in the Chinese context. It depends on how policymakers and societies understand the role of universities (promote excellency versus distributing human capital) and see their responsibility in promoting social inclusion. There is no general rule about how regions should proceed because it depends on their historical context and productive structure. Education can be understood either as a factor of production with instrumental value or as an entitlement with intrinsic value (Sen, 2009, 2017). Those provinces that see HEIs more closely linked to the notions of excellency and intrinsic value might emphasize more the importance of investing in quality at the expense of including larger masses of people. Alternatively, those provinces that see the role of universities focused on the promotion of social inclusion as part of a rights view of education, might be more committed to quantity at the expense of quality. It is difficult however to categorize trade-offs given the diversity of circumstances that might shape both aspects given China's rapid economic development. However, given the relevance of both quantity and quality, it would be a mistake to ignore these trade-offs. Instead, by taking both aspects on board one can evaluate the policies that manage to harmonize these objectives in relation to those that decide to choose only one of them.

The findings of the paper contribute to several strands of research. A series of articles including Heckman (2005), Garnaut (2010), Cai (2013), and Glazebrook and Song (2013), argue that countries that have passed the Lewis turning point need to improve the quality of their tertiary education to gain a competitive advantage in the global economy. The experience of other countries in expanding higher education provides a glimpse of the challenges awaiting China. Furthermore, the results in Li, Liu, et al., 2014, Li, Whalley, & Xing, 2014, Valerio Mendoza (2018), Fraumeni et al. (2019), Zhang et al. (2019), and Valerio Mendoza et al. (2021) suggest that the evolution of human capital within China over the past decades is strongly related to the supply of higher education institutions. Similarly, the estimates also provide insights into related research on educational inequality and the avoidance of the middle-income trap, since they illustrate which provinces have an insufficient supply of higher education institutions, both in terms of quantity and quality, relative to their respective populations. For instance, several border provinces with large ethnic minorities, including Inner Mongolia, Guangxi, Xinjiang, and Yunnan, are ranked low for both the *CHEDI* and *CHEQI*, indicating that the density and quality of higher education in these regions may not meet their corresponding demand. In the same way, these indicators can explain within-country migration flows and should be the focus of further research. Especially if the provinces with an undersupply of higher education institutions are also experiencing an outflow of migrants while those with an oversupply are undergoing an inflow of people.

As the country pursues high-income status in the next couple of decades, the role of higher education becomes even more pivotal in meeting the future needs of the Chinese economy. In order to generate a skilled labor force comparable to that of developed countries, the PRC must continue to expand the supply of higher education. Zhang et al. (2020) argue that the disparities in education development between Chinese provinces have become an important factor restricting the overall progress of China's society. The burgeoning evidence in turn calls for the need for greater prioritization and implementation of government policies, such as the "Central and Western Higher Education Revitalization Plan" (Ministry of Education, 2016), targeted at improving the quality and optimizing the geographical structure of tertiary education, to favor Central and Western regions that are poor in higher education resources. Likewise, market-oriented, i.e., private, tertiary education can help aid the state in meeting the growing demand.

The higher education indices presented here are simple yet comprehensive, therefore they may provide useful guidance to Chinese authorities in shaping public policy decisions, especially as to which areas need to further improve their supply of HEIs in terms of quantity and quality. In this regard, the results of the poset analysis additionally indicate that the 31 provinces of China could be grouped in as much as 14 levels, or ranks, according to their quantity and quality dimensions, which could help policymakers in achieving a less arbitrary and more even distribution of education resources. Finally, the *CHEDI*, *CHEQI*, and *CHEI* can also serve as indicators that signal the competitiveness of each province since universities are considered a crucial component for the whole economic system because they are the major contributor to innovation, both in science and industry. The growing importance of technological automation and artificial intelligence further highlights the inevitably rising demand for high-skilled labor (Xie et al., 2021). Existing and additional resources can thus be targeted to ensuring regions with low density and quality are able to develop the necessary human capital in the future. In addition, the use of these indices can contribute towards higher education policies with greater fairness of opportunities. By doing so it can anticipate and avoid the current European debate about left-behind areas and how leveling-up policies can try to mend policy failures accumulated for decades (Tomaney & Pike, 2020). Because financial and administrative decentralization have already been put in place by the Chinese government, different policy instruments and indicators, such as the ones presented here, can be helpful in promoting a more balanced and prosperous higher education strategy in China.

Declarations of interest

None.

Data Statement

The data that support the findings of this study are openly available in Valerio Mendoza, Borsi, and Comim (2021).

Appendix A. The Chinese Higher Education Density Index using the total supply of higher education institutions, four-year undergraduate colleges, two-year colleges, and private institutions (2001–2017)

Table A1
Chinese Higher Education Density Index (*CHEDI*): Total.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Beijing	Tianjin	Ningxia	Shanghai	Liaoning	Shaanxi	Jilin	Fujian	Hubei	Jiangxi	Shanxi	Heilongjiang	Chongqing	I. Mongolia	Jiangsu	Tibet
2001	5.003	3.388	1.458	2.689	1.790	1.378	1.525	1.091	1.060	0.869	0.932	1.262	0.795	0.888	1.116	1.338
2002	4.398	3.509	1.235	2.795	1.585	1.291	1.309	0.879	1.012	0.741	1.011	1.271	0.942	0.891	1.067	1.134
2003	4.199	3.242	1.833	2.900	1.473	1.248	1.311	0.991	1.063	1.000	1.176	1.231	0.821	0.819	1.113	1.313
2004	4.045	3.146	1.644	2.635	1.356	1.261	1.189	1.170	1.004	1.034	1.159	1.160	0.877	0.912	1.138	1.176

(*continued on next page*)

Table A1 (*continued*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Beijing	Tianjin	Ningxia	Shanghai	Liaoning	Shaanxi	Jilin	Fujian	Hubei	Jiangxi	Shanxi	Heilongjiang	Chongqing	I. Mongolia	Jiangsu	Tibet
2005	3.669	2.843	1.578	2.400	1.217	1.400	1.172	1.023	1.077	1.107	1.272	1.155	0.853	0.970	1.074	1.045
2006	3.580	2.962	1.523	2.339	1.259	1.440	1.143	1.114	1.056	1.076	1.174	1.166	0.932	0.974	1.068	1.259
2007	3.334	2.808	1.450	2.198	1.251	1.380	1.097	1.368	1.027	1.028	1.183	1.210	0.918	1.047	1.053	1.438
2008	3.209	2.544	1.430	2.197	1.245	1.374	1.069	1.358	1.036	1.066	1.216	1.227	0.958	1.042	1.063	1.422
2009	3.112	2.440	1.385	2.115	1.326	1.342	1.094	1.377	1.036	1.082	1.224	1.201	1.002	1.072	1.052	1.378
2010	2.778	2.275	1.349	1.768	1.366	1.372	1.100	1.316	1.020	1.060	1.194	1.199	1.047	1.116	1.035	1.309
2011	2.591	2.119	1.398	1.685	1.368	1.330	1.114	1.303	1.064	1.038	1.172	1.215	1.137	1.157	1.018	1.263
2012	2.529	2.008	1.364	1.669	1.350	1.327	1.100	1.295	1.047	1.050	1.170	1.266	1.135	1.165	1.019	1.228
2013	2.449	1.885	1.320	1.659	1.433	1.310	1.143	1.274	1.031	1.077	1.189	1.254	1.183	1.160	1.010	1.186
2014	2.368	1.799	1.466	1.650	1.437	1.286	1.146	1.259	1.033	1.095	1.181	1.234	1.156	1.162	1.021	1.145
2015	2.260	1.568	1.411	1.496	1.427	1.308	1.136	1.236	1.133	1.145	1.162	1.146	1.126	1.138	1.095	0.998
2016	2.227	1.872	1.418	1.406	1.409	1.297	1.167	1.208	1.157	1.135	1.155	1.148	1.134	1.118	1.103	0.964
2017	2.236	1.932	1.470	1.397	1.389	1.280	1.204	1.201	1.153	1.142	1.140	1.128	1.115	1.106	1.098	1.096

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Hainan	Qinghai	Guizhou	Xinjiang	Anhui	Zhejiang	Gansu	Hunan	Hebei	Yunnan	Guangxi	Shandong	Henan	Guangdong	Sichuan
2001	1.179	1.570	0.772	1.188	0.760	0.890	0.774	0.925	0.893	0.657	0.735	0.726	0.638	0.784	0.570
2002	1.131	1.527	0.789	1.113	0.876	1.260	0.973	0.868	1.004	0.652	0.628	0.711	0.683	0.861	0.570
2003	0.983	1.991	0.778	1.191	0.857	1.174	0.987	0.771	0.955	0.709	0.693	0.738	0.596	0.824	0.570
2004	1.083	1.793	0.743	1.067	0.910	1.092	0.953	0.890	0.993	0.620	0.741	0.746	0.588	0.892	0.572
2005	1.310	1.465	0.659	1.080	0.957	0.989	0.920	1.063	0.919	0.715	0.776	0.767	0.640	0.795	0.599
2006	1.270	1.420	0.659	1.070	0.938	0.952	0.896	1.049	0.872	0.789	0.795	0.790	0.625	0.776	0.624
2007	1.208	1.356	0.669	1.007	0.990	0.982	0.884	1.060	0.863	0.769	0.799	0.799	0.596	0.785	0.636
2008	1.194	0.982	0.663	1.021	1.020	0.983	0.880	1.023	0.837	0.763	0.819	0.823	0.606	0.769	0.652
2009	1.233	0.956	0.684	0.987	1.032	0.990	0.859	0.977	0.862	0.787	0.809	0.816	0.625	0.746	0.643
2010	1.209	0.933	0.736	0.962	1.091	0.953	0.898	0.980	0.849	0.785	0.869	0.822	0.677	0.717	0.645
2011	1.164	0.899	0.736	0.924	1.112	0.934	0.921	1.016	0.828	0.785	0.838	0.834	0.734	0.711	0.634
2012	1.208	0.880	0.742	0.960	1.127	0.921	0.905	1.007	0.822	0.798	0.821	0.807	0.751	0.714	0.671
2013	1.171	0.853	0.775	0.980	1.084	0.897	0.884	0.986	0.849	0.789	0.797	0.804	0.779	0.701	0.692
2014	1.142	1.145	0.813	1.030	1.067	0.903	0.890	0.981	0.830	0.772	0.778	0.806	0.778	0.707	0.723
2015	1.006	1.100	0.871	1.005	1.044	1.022	0.933	0.986	0.857	0.785	0.798	0.783	0.734	0.706	0.716
2016	1.044	1.076	0.957	1.020	1.021	1.018	0.998	0.959	0.854	0.802	0.802	0.770	0.720	0.711	0.702
2017	1.083	1.059	1.032	1.014	1.004	0.998	0.985	0.954	0.849	0.846	0.799	0.765	0.740	0.713	0.693

Note: Chinese Higher Education Density Index using the total supply of higher education institutions (Total) for 31 provinces from 2001 to 2017. Provinces are listed in descending order according to the final observation. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001–2018.

Table A2
Chinese Higher Education Density Index (*CHEDI*): Four-year.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Beijing	Tianjin	Shanghai	Liaoning	Shaanxi	Jilin	Tibet	Ningxia	Hubei	Zhejiang	Heilongjiang	Jiangsu	Fujian	Jiangxi	Shanxi	Gansu
2001	8.193	3.833	3.047	1.835	1.636	1.589	2.439	1.519	1.073	0.927	1.178	1.221	0.684	0.817	0.849	0.913
2002	7.692	3.623	2.994	1.736	1.490	1.577	2.278	1.063	1.117	0.960	1.116	1.153	0.824	0.816	0.862	0.938
2003	7.613	3.588	2.827	1.819	1.638	1.640	2.239	1.042	1.041	0.990	1.162	1.143	0.809	0.805	0.851	1.006
2004	7.526	3.527	3.110	1.808	1.625	1.629	2.197	1.024	1.034	0.978	1.156	1.134	0.800	0.796	0.842	0.996
2005	6.713	3.182	3.111	1.747	1.636	1.629	1.997	1.237	1.066	0.979	1.207	1.061	0.730	0.855	0.879	0.853
2006	6.788	2.995	2.956	1.675	1.772	1.576	1.909	1.481	1.037	0.970	1.170	1.019	0.855	0.824	0.848	0.892
2007	6.227	2.830	2.925	1.632	1.731	1.606	1.852	1.437	1.077	0.970	1.146	1.012	0.930	0.803	0.878	0.871
2008	5.929	2.800	2.845	1.606	1.796	1.584	1.811	1.402	1.062	1.015	1.133	0.993	0.962	0.788	0.864	0.857
2009	5.651	2.646	2.759	1.702	1.768	1.622	1.769	1.368	1.046	0.990	1.162	0.974	0.943	0.772	0.848	0.908
2010	4.979	2.463	2.267	1.655	1.759	1.655	1.679	1.330	1.029	1.020	1.186	0.963	1.003	0.830	0.848	0.921
2011	4.615	2.292	2.159	1.678	1.747	1.665	1.618	1.279	1.107	0.987	1.322	0.952	1.011	0.874	0.864	0.893
2012	4.415	2.155	2.088	1.643	1.794	1.632	1.561	1.486	1.109	0.966	1.421	0.931	0.984	0.854	0.843	0.933
2013	4.237	1.995	2.111	1.760	1.724	1.685	1.486	1.418	1.093	0.956	1.410	0.934	0.942	0.923	0.894	0.958
2014	4.065	1.857	2.139	1.789	1.689	1.670	1.399	1.344	1.096	0.942	1.392	0.950	0.935	0.947	0.935	0.916
2015	3.419	2.108	1.770	1.668	1.631	1.512	1.041	1.308	1.288	1.157	1.121	1.086	1.025	1.035	0.952	0.952
2016	3.391	2.144	1.753	1.657	1.610	1.511	1.012	1.323	1.290	1.178	1.146	1.075	1.066	1.021	1.001	0.941
2017	3.447	2.152	1.755	1.636	1.602	1.521	1.326	1.310	1.287	1.165	1.150	1.071	1.057	1.039	0.996	0.936

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Chongqing	Hebei	Guizhou	Hainan	Hunan	Guangxi	Xinjiang	Anhui	I. Mongolia	Shandong	Qinghai	Yunnan	Sichuan	Henan	Guangdong
2001	0.966	0.702	0.507	1.074	0.616	0.580	1.140	0.676	0.899	0.757	1.635	0.648	0.544	0.470	0.852
2002	1.044	0.783	0.528	1.010	0.703	0.546	1.170	0.768	0.852	0.737	1.533	0.655	0.584	0.506	0.800

(*continued on next page*)

Table A2 (*continued*)

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Chongqing	Hebei	Guizhou	Hainan	Hunan	Guangxi	Xinjiang	Anhui	I. Mongolia	Shandong	Qinghai	Yunnan	Sichuan	Henan	Guangdong
2003	0.901	0.774	0.521	0.994	0.665	0.581	1.146	0.755	0.847	0.729	1.510	0.737	0.579	0.500	0.785
2004	1.028	0.766	0.514	0.981	0.659	0.575	1.124	0.745	0.842	0.721	1.489	0.727	0.621	0.496	0.749
2005	0.988	0.807	0.544	0.891	0.758	0.593	1.009	0.813	0.773	0.778	1.019	0.663	0.629	0.550	0.722
2006	0.955	0.778	0.666	1.070	0.733	0.720	0.960	0.790	0.746	0.769	0.979	0.638	0.657	0.533	0.711
2007	0.934	0.833	0.652	1.037	0.745	0.699	0.921	0.860	0.729	0.767	0.953	0.660	0.647	0.581	0.687
2008	0.916	0.818	0.640	1.015	0.760	0.684	0.894	0.876	0.718	0.828	0.938	0.648	0.639	0.606	0.672
2009	0.897	0.802	0.765	0.990	0.747	0.704	0.871	0.865	0.847	0.812	0.921	0.711	0.648	0.595	0.656
2010	0.876	0.819	0.823	0.969	0.795	0.731	0.848	0.876	0.818	0.843	0.897	0.695	0.649	0.627	0.613
2011	0.840	0.813	0.801	0.932	0.768	0.739	0.814	0.904	0.790	0.848	0.863	0.706	0.650	0.662	0.607
2012	0.925	0.814	0.782	1.084	0.748	0.753	0.933	0.883	0.837	0.811	0.839	0.757	0.675	0.665	0.605
2013	0.936	0.843	0.794	1.036	0.739	0.753	0.887	0.846	0.804	0.810	0.802	0.725	0.686	0.689	0.595
2014	0.942	0.823	0.761	0.985	0.792	0.748	0.839	0.804	0.769	0.818	0.763	0.723	0.729	0.691	0.636
2015	0.932	0.879	0.860	0.741	0.846	0.844	0.858	0.805	0.761	0.765	0.765	0.735	0.699	0.617	0.643
2016	0.916	0.912	0.848	0.852	0.835	0.831	0.838	0.811	0.753	0.752	0.753	0.725	0.689	0.644	0.629
2017	0.908	0.906	0.905	0.844	0.830	0.823	0.822	0.804	0.751	0.748	0.747	0.744	0.686	0.643	0.640

Note: Chinese Higher Education Density Index using four-year undergraduate colleges (Four-year) for 31 provinces from 2001 to 2017. Provinces are listed in descending order according to the final observation. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001–2018.

Table A3

Chinese Higher Education Density Index (*CHEDI*): Two-year.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Tianjin	Ningxia	I. Mongolia	Qinghai	Fujian	Chongqing	Hainan	Shanxi	Jiangxi	Xinjiang	Anhui	Liaoning	Beijing	Guizhou	Jiangsu	Heilongjiang
2001	2.846	1.384	0.874	1.490	1.586	0.587	1.306	1.032	0.931	1.246	0.862	1.734	1.127	1.094	0.989	1.363
2002	3.395	1.406	0.930	1.521	0.934	0.841	1.252	1.160	0.667	1.056	0.984	1.435	1.131	1.048	0.981	1.424
2003	2.971	2.453	0.797	2.368	1.133	0.758	0.975	1.431	1.152	1.226	0.937	1.202	1.520	0.980	1.089	1.285
2004	2.890	2.059	0.959	1.997	1.418	0.776	1.151	1.371	1.193	1.028	1.020	1.053	1.712	0.896	1.140	1.163
2005	2.625	1.798	1.098	1.754	1.212	0.766	1.581	1.526	1.270	1.125	1.050	0.874	1.703	0.734	1.083	1.122
2006	2.940	1.551	1.123	1.709	1.283	0.917	1.400	1.388	1.241	1.142	1.035	0.987	1.481	0.654	1.101	1.164
2007	2.793	1.459	1.249	1.612	1.646	0.909	1.316	1.377	1.171	1.062	1.073	1.009	1.499	0.680	1.079	1.251
2008	2.379	1.449	1.252	1.010	1.615	0.986	1.310	1.444	1.246	1.103	1.113	1.012	1.453	0.679	1.108	1.287
2009	2.310	1.396	1.216	0.979	1.654	1.068	1.389	1.464	1.280	1.061	1.139	1.086	1.492	0.632	1.101	1.226
2010	2.155	1.361	1.307	0.956	1.516	1.157	1.363	1.416	1.206	1.035	1.229	1.181	1.372	0.681	1.081	1.208
2011	1.992	1.462	1.380	0.914	1.479	1.316	1.302	1.358	1.134	0.987	1.235	1.161	1.286	0.688	1.052	1.137
2012	1.898	1.275	1.367	0.900	1.486	1.261	1.279	1.371	1.168	0.970	1.274	1.151	1.296	0.710	1.068	1.157
2013	1.812	1.255	1.396	0.887	1.495	1.347	1.261	1.385	1.180	1.042	1.242	1.215	1.261	0.762	1.060	1.150
2014	1.760	1.551	1.435	1.409	1.484	1.304	1.251	1.351	1.198	1.162	1.249	1.193	1.193	0.849	1.071	1.125
2015	1.727	1.494	1.474	1.398	1.419	1.295	1.241	1.346	1.238	1.132	1.255	1.196	1.184	0.873	1.095	1.159
2016	1.625	1.504	1.450	1.370	1.337	1.332	1.218	1.296	1.238	1.186	1.213	1.183	1.168	1.057	1.130	1.149
2017	1.735	1.613	1.424	1.338	1.330	1.301	1.296	1.270	1.234	1.186	1.183	1.168	1.152	1.146	1.121	1.109

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Shanghai	Hunan	Hubei	Gansu	Shaanxi	Yunnan	Jilin	Tibet	Zhejiang	Henan	Hebei	Shandong	Guangdong	Guangxi	Sichuan
2001	2.254	1.300	1.044	0.605	1.065	0.667	1.448	0.000	0.845	0.843	1.125	0.690	0.701	0.922	0.601
2002	2.599	1.031	0.907	1.008	1.095	0.650	1.043	0.000	1.558	0.858	1.224	0.686	0.921	0.709	0.556
2003	2.957	0.854	1.080	0.972	0.943	0.686	1.052	0.586	1.317	0.671	1.098	0.745	0.855	0.781	0.563
2004	2.317	1.044	0.984	0.925	1.017	0.548	0.894	0.491	1.169	0.651	1.146	0.762	0.988	0.853	0.540
2005	1.942	1.261	1.084	0.964	1.248	0.749	0.877	0.430	0.996	0.698	0.990	0.759	0.842	0.894	0.580
2006	1.935	1.255	1.069	0.898	1.222	0.888	0.860	0.833	0.940	0.686	0.933	0.805	0.818	0.843	0.602
2007	1.736	1.260	0.995	0.893	1.157	0.838	0.774	1.175	0.989	0.606	0.881	0.819	0.848	0.863	0.630
2008	1.778	1.193	1.019	0.894	1.101	0.838	0.737	1.170	0.962	0.605	0.849	0.820	0.833	0.906	0.660
2009	1.703	1.124	1.030	0.828	1.070	0.835	0.756	1.128	0.990	0.644	0.899	0.818	0.804	0.876	0.640
2010	1.449	1.098	1.015	0.883	1.124	0.842	0.745	1.073	0.909	0.710	0.868	0.808	0.784	0.957	0.642
2011	1.371	1.165	1.028	0.931	1.054	0.830	0.755	1.028	1.083	0.774	0.832	0.819	0.771	0.894	0.619
2012	1.387	1.165	0.999	0.880	1.017	0.819	0.750	1.004	1.073	0.800	0.821	0.799	0.779	0.859	0.664
2013	1.359	1.150	0.991	0.834	1.036	0.832	0.783	0.986	0.858	0.839	0.853	0.801	0.771	0.826	0.696
2014	1.312	1.113	0.989	0.872	1.006	0.806	0.783	0.969	0.876	0.838	0.834	0.797	0.756	0.799	0.719

(*continued on next page*)

Table A3 (*continued*)

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Shanghai	Hunan	Hubei	Gansu	Shaanxi	Yunnan	Jilin	Tibet	Zhejiang	Henan	Hebei	Shandong	Guangdong	Guangxi	Sichuan
2015	1.234	1.106	0.984	0.909	1.003	0.824	0.784	0.952	0.891	0.835	0.831	0.793	0.758	0.750	0.727
2016	1.091	1.072	1.035	1.050	1.012	0.873	0.854	0.920	0.872	0.788	0.802	0.786	0.785	0.777	0.713
2017	1.076	1.064	1.034	1.028	0.991	0.938	0.920	0.890	0.849	0.827	0.798	0.780	0.779	0.778	0.699

Note: Chinese Higher Education Density Index using two-year vocational colleges (Two-year) for 31 provinces from 2001 to 2017. Provinces are listed in descending order according to the final observation. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001–2018.

Table A4
Chinese Higher Education Density Index (*CHEDI*): Private.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Fujian	Hainan	Chongqing	Shanghai	Shaanxi	Tianjin	Liaoning	Beijing	Hubei	Jiangxi	Jilin	Jiangsu	Zhejiang	Ningxia	Anhui	Guangxi
2001	2.485	3.579	1.840	6.178	1.947	2.838	1.359	3.090	0.954	1.021	1.588	0.387	2.530	0.618	1.126	0.298
2002	2.819	3.024	1.563	6.725	1.653	1.206	1.445	2.560	0.608	1.150	1.350	1.152	2.123	1.045	0.958	0.252
2003	1.900	1.021	1.323	6.777	2.693	0.819	0.984	3.982	1.242	1.558	0.919	0.224	1.428	1.239	0.904	0.171
2004	2.941	0.842	1.102	5.927	2.230	0.672	0.816	3.689	1.030	1.446	0.762	1.389	1.171	1.021	0.852	0.563
2005	2.278	1.945	0.959	4.832	2.165	0.515	0.763	3.840	0.940	1.245	0.791	1.221	1.802	0.987	0.702	0.691
2006	2.376	1.685	1.003	4.139	2.137	0.437	1.099	2.970	0.825	1.082	0.690	1.244	1.555	0.943	0.692	0.796
2007	2.829	1.564	0.938	3.792	1.998	0.395	1.025	2.697	0.850	1.008	0.645	1.213	1.444	0.957	0.936	0.831
2008	2.626	2.409	1.014	3.704	1.859	0.350	1.239	2.427	0.792	1.216	0.602	1.179	1.331	1.045	1.006	1.025
2009	2.826	2.737	1.241	3.283	1.881	0.321	1.460	2.246	0.758	1.156	0.575	1.174	1.261	0.989	1.093	0.893
2010	2.683	2.631	1.189	2.648	1.837	0.293	1.394	1.942	0.732	1.110	0.694	1.162	1.204	0.910	1.088	0.992
2011	2.427	2.376	1.784	2.367	1.670	0.256	1.426	1.720	0.965	1.083	0.758	1.099	1.087	0.826	1.106	0.897
2012	2.320	2.640	1.704	2.248	1.604	0.237	1.295	1.617	0.984	1.188	0.730	1.056	1.034	0.794	1.117	0.857
2013	2.202	2.500	1.829	2.382	1.528	0.217	1.529	1.511	0.937	1.131	1.046	1.006	0.977	0.756	1.060	0.880
2014	2.177	2.379	1.744	2.277	1.463	0.202	1.537	1.426	1.002	1.149	1.115	1.041	0.927	0.780	1.009	0.775
2015	1.778	1.457	1.509	1.492	1.500	1.348	1.471	1.310	1.361	1.288	1.171	1.189	1.103	1.164	0.957	0.870
2016	1.745	1.638	1.601	1.474	1.477	1.322	1.458	1.382	1.372	1.267	1.236	1.173	1.112	1.142	0.939	0.931
2017	1.739	1.632	1.597	1.484	1.478	1.456	1.427	1.392	1.344	1.267	1.251	1.153	1.135	1.108	0.936	0.928

	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	Hebei	Hunan	Heilongjiang	Guangdong	Guizhou	Yunnan	Sichuan	Shanxi	Shandong	I. Mongolia	Henan	Xinjiang	Gansu	Qinghai	Tibet
2001	0.851	0.432	0.748	1.464	0.375	0.665	0.330	0.435	1.103	0.599	0.596	0	0.553	0	0
2002	0.721	0.366	0.637	1.391	0.316	0.560	0.560	0.369	1.070	0.510	0.632	0	0.468	0	0
2003	1.468	0.622	0.651	0.937	0.214	0.379	0.476	0.250	1.452	0.348	0.685	0	0.318	0	0
2004	1.213	0.514	0.721	0.995	0.176	0.312	0.473	0.413	1.200	0.289	0.567	0	0.263	0	0
2005	0.940	0.849	0.703	1.343	0.144	0.724	0.392	0.800	1.161	0.225	0.515	0.534	0.207	0	0
2006	0.953	0.814	0.860	1.211	0.125	0.733	0.517	0.696	1.211	0.979	0.500	0.687	0.180	0	0
2007	0.888	0.901	0.806	1.305	0.117	0.683	0.488	0.779	1.128	0.916	0.471	0.631	0.168	0	0
2008	0.824	0.838	0.860	1.207	0.108	0.724	0.556	0.724	1.049	0.852	0.480	0.579	0.157	0	0
2009	0.897	0.800	0.824	1.104	0.104	0.776	0.530	0.805	0.999	0.814	0.540	0.548	0.150	0	0
2010	0.848	0.870	0.795	1.095	0.110	0.828	0.521	0.746	0.994	0.925	0.729	0.523	0.149	0	0
2011	0.767	0.790	0.996	1.058	0.200	0.900	0.518	0.677	0.973	0.979	0.888	0.472	0.135	0	0
2012	0.734	0.806	1.396	1.010	0.288	0.933	0.621	0.648	0.898	1.075	0.925	0.449	0.130	0	0
2013	0.785	0.764	1.333	0.991	0.274	0.886	0.788	0.616	0.854	1.024	0.917	0.424	0.124	0	0
2014	0.748	0.729	1.281	1.030	0.262	0.846	0.867	0.589	0.878	0.980	0.943	0.534	0.237	0	0
2015	0.894	0.867	0.895	0.874	0.591	0.800	0.786	0.776	0.732	0.755	0.740	0.723	0.511	0.323	0
2016	0.880	0.853	0.840	0.870	0.739	0.787	0.773	0.765	0.736	0.745	0.729	0.705	0.503	0.317	0
2017	0.904	0.854	0.847	0.846	0.791	0.787	0.774	0.765	0.755	0.747	0.731	0.695	0.504	0.316	0

Note: Chinese Higher Education Density Index using private higher education institutions (Private) for 31 provinces from 2001 to 2017. Provinces are listed in descending order according to the final observation. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001–2018.

Appendix B. The Chinese Higher Education Quality Index and the Chinese Higher Education Index: 2013–2017

Table B1
Chinese Higher Education Quality Index (*CHEQI*): 2013–2017.

Rank (2017)	Province	2013	2015	2016	2017
1	Beijing	0.440	0.726	0.718	0.702

(continued on next page)

Table B1 (*continued*)

Rank (2017)	Province	2013	2015	2016	2017
2	Shanghai	0.227	0.359	0.351	0.347
3	Tianjin	0.150	0.336	0.293	0.265
4	Shaanxi	0.120	0.185	0.198	0.203
5	Liaoning	0.086	0.250	0.220	0.174
6	Jilin	0.049	0.186	0.183	0.161
7	Hubei	0.089	0.129	0.166	0.158
8	Jiangsu	0.121	0.177	0.176	0.153
9	Zhejiang	0.085	0.148	0.140	0.146
10	Heilongjiang	0.074	0.157	0.152	0.123
11	Chongqing	0.042	0.115	0.123	0.121
12	Hunan	0.047	0.111	0.104	0.104
13	Fujian	0.045	0.138	0.115	0.103
14	Gansu	0.056	0.073	0.094	0.096
15	Anhui	0.048	0.088	0.110	0.093
16	Shanxi	0.037	0.111	0.102	0.087
17	Qinghai	0.000	0.090	0.077	0.080
18	Jiangxi	0.022	0.096	0.091	0.079
19	Hainan	0.000	0.105	0.087	0.078
20	Sichuan	0.035	0.077	0.089	0.078
21	Shandong	0.030	0.102	0.089	0.077
22	Henan	0.031	0.075	0.079	0.075
23	Guangdong	0.039	0.085	0.088	0.075
24	Hebei	0.031	0.090	0.084	0.072
25	Ningxia	0.000	0.133	0.115	0.071
26	Inner Mongolia	0.013	0.045	0.071	0.065
27	Yunnan	0.007	0.058	0.080	0.064
28	Guangxi	0.030	0.066	0.084	0.063
29	Tibet	0.000	0.079	0.050	0.057
30	Xinjiang	0.013	0.075	0.065	0.055
31	Guizhou	0.010	0.047	0.064	0.048

Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores obtained by higher education institutions listed in the 2015, 2017, 2018, and 2019 Best Chinese Universities Ranking for the 31 provinces of China. Provinces are ranked in descending order according to the 2017 results. Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

Table B2
Chinese Higher Education Index: 2013–2017.

Rank (2017)	Province	2013	2015	2016	2017
1	Beijing	1	1	1	1
2	Tianjin	0.363	0.479	0.457	0.435
3	Shanghai	0.467	0.436	0.429	0.427
4	Shaanxi	0.291	0.284	0.289	0.290
5	Liaoning	0.258	0.338	0.314	0.273
6	Jilin	0.206	0.263	0.260	0.243
7	Hubei	0.169	0.181	0.206	0.199
8	Zhejiang	0.146	0.172	0.167	0.168
9	Jiangsu	0.184	0.180	0.175	0.157
10	Heilongjiang	0.196	0.172	0.170	0.148
11	Ningxia	0.113	0.188	0.175	0.137
12	Tibet	0.122	0.101	0.069	0.129
13	Fujian	0.099	0.141	0.128	0.116
14	Chongqing	0.095	0.107	0.107	0.104
15	Jiangxi	0.071	0.112	0.102	0.095
16	Shanxi	0.084	0.108	0.107	0.093
17	Gansu	0.114	0.080	0.089	0.089
18	Hunan	0.073	0.089	0.078	0.076
19	Hebei	0.069	0.080	0.077	0.066
20	Anhui	0.089	0.065	0.078	0.063
21	Hainan	0.060	0.066	0.068	0.059
22	Guizhou	0.038	0.044	0.051	0.047
23	Guangxi	0.055	0.056	0.062	0.044
24	Qinghai	0.028	0.059	0.043	0.043
25	Shandong	0.064	0.068	0.052	0.042
26	Xinjiang	0.055	0.065	0.050	0.037
27	Inner Mongolia	0.044	0.026	0.038	0.033

(continued on next page)

Table B2 (*continued*)

Rank (2017)	Province	2013	2015	2016	2017
28	Yunnan	0.026	0.030	0.040	0.031
29	Sichuan	0.052	0.038	0.041	0.031
30	Henan	0.049	0.022	0.025	0.021
31	Guangdong	0.045	0.034	0.029	0.020

Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2015, 2017, 2018, and 2019 Best Chinese Universities Ranking for the 31 provinces of China. Provinces are ranked in descending order according to the 2017 results. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

Appendix C. *CHEDI*, *CHEQI*, and *CHEI* results, excluding Beijing

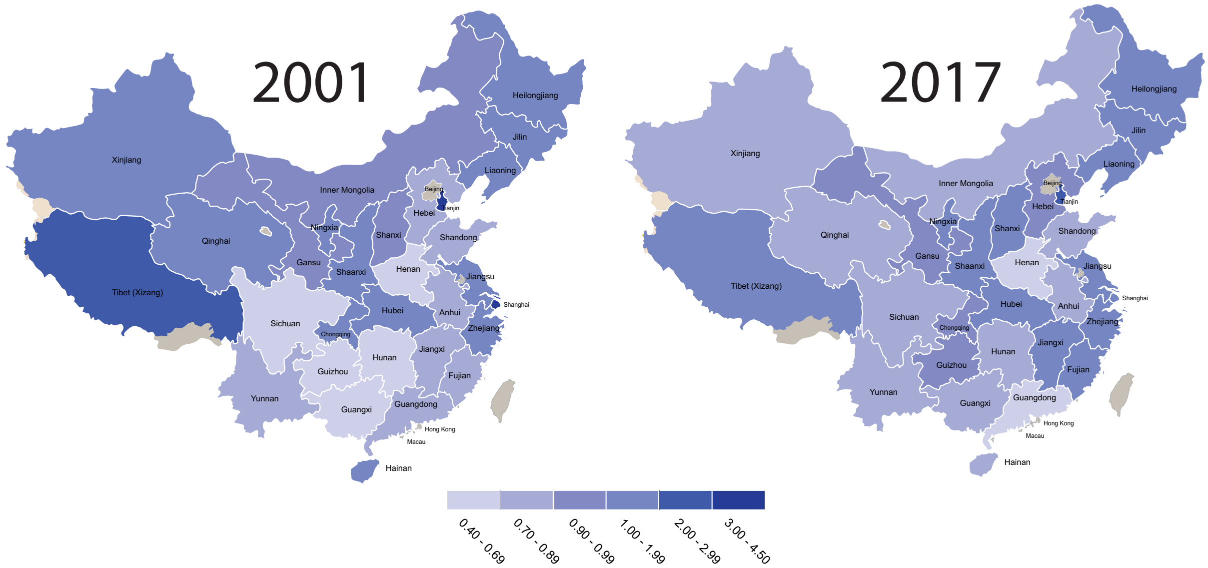


Fig. C1. Chinese Higher Education Density Index for 2001 and 2017, excluding Beijing: Four-year.
Note: Chinese Higher Education Density Index using four-year undergraduate colleges (Four-year). Sample: 30 Chinese provinces, 2001 and 2017 (Beijing excluded). Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education and the China Statistical Yearbooks 2001 and 2018.

Table C1
Chinese Higher Education Quality Index (*CHEQI*), excluding Beijing: 2017.

Rank	Province	*CHEQI*
1	Shanghai	0.347
2	Tianjin	0.265
3	Shaanxi	0.203
4	Liaoning	0.174
5	Jilin	0.161
6	Hubei	0.158
7	Jiangsu	0.153
8	Zhejiang	0.146
9	Heilongjiang	0.123
10	Chongqing	0.121
11	Hunan	0.104
12	Fujian	0.103
13	Gansu	0.096
14	Anhui	0.093

(*continued on next page*)

Table C1 (*continued*)

Rank	Province	*CHEQI*
15	Shanxi	0.087
16	Qinghai	0.080
17	Jiangxi	0.079
18	Hainan	0.078
19	Sichuan	0.078
20	Shandong	0.077
21	Henan	0.075
22	Guangdong	0.075
23	Hebei	0.072
24	Ningxia	0.071
25	Inner Mongolia	0.065
26	Yunnan	0.064
27	Guangxi	0.063
28	Tibet	0.057
29	Xinjiang	0.055
30	Guizhou	0.048

Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for all provinces of China, excluding Beijing. Provinces are ranked in descending order. Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

Fig. C2. Chinese Higher Education Quality Index (*CHEQI*), excluding Beijing: 2017.
Note: Chinese Higher Education Quality Index (*CHEQI*) based on the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for all provinces of China, excluding Beijing. Source: own elaboration using the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

Table C2
Chinese Higher Education Index, excluding Beijing: 2017.

Rank	Province	*CHEI*
1	Shanghai	0.869
2	Tianjin	0.864
3	Shaanxi	0.578
4	Liaoning	0.540
5	Jilin	0.480
6	Hubei	0.398
7	Zhejiang	0.337
8	Jiangsu	0.319
9	Heilongjiang	0.393
10	Ningxia	0.259
11	Tibet	0.242
12	Fujian	0.229
13	Chongqing	0.211
14	Jiangxi	0.183
15	Shanxi	0.182
16	Gansu	0.178
17	Hunan	0.156
18	Anhui	0.129
19	Hebei	0.129
20	Hainan	0.118
21	Qinghai	0.088
22	Guizhou	0.088
23	Guangxi	0.086
24	Shandong	0.085
25	Xinjiang	0.071
26	Sichuan	0.065
27	Inner Mongolia	0.065
28	Yunnan	0.062
29	Henan	0.046
30	Guangdong	0.044

Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for all provinces of China, excluding Beijing. Provinces are ranked in descending order. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

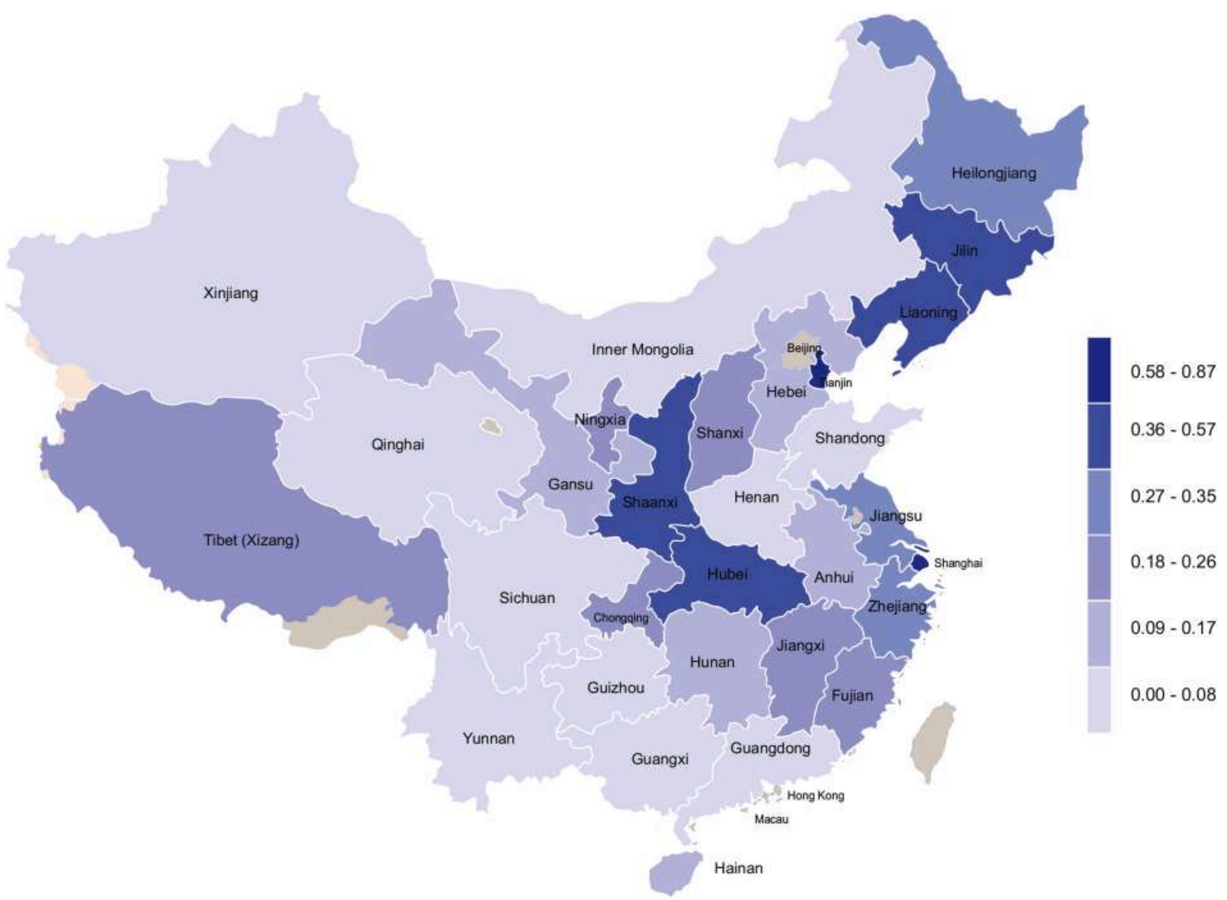


Fig. C3. Chinese Higher Education Index: 2017.
Note: Chinese Higher Education Index (*CHEI*) based on four-year undergraduate colleges and the overall scores obtained by higher education institutions listed in the 2019 Best Chinese Universities Ranking for all provinces of China, excluding Beijing. Source: own elaboration using the List of National Colleges and Universities issued by the Ministry of Education, the China Statistical Yearbook 2018, and the Shanghai Jiao Tong Academic Ranking of World Universities (ARWU).

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