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## The great Chinese inequality turnaround

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## ABSTRACT

This paper argues that after a quarter century of sharp and sustained increase, Chinese inequality is now plateauing and, according to some measures, even declining. A number of papers have been harbingers of this conclusion, but this paper consolidates the literature indicating a turnaround, and provides empirical foundations for it. The argument is made using a range of data sources and a range of measures and perspectives on inequality. The evolution of inequality is further examined through decomposition by income source and population subgroup. Some preliminary explanations are provided for these trends in terms of shifts in policy and the structural transformation of the Chinese economy. We relate the turnaround to two classic phenomena in the development economics literature—the Lewis turning point and the Kuznets turning point. The plateauing is not yet a full blown decline, and there are short term variations. But the narrative on Chinese inequality now needs to accommodate the possibility of a turnaround in inequality, and to focus on the reasons for this turnaround.

## 1. Introduction

Alongside the spectacular growth and extraordinary reductions in poverty, perhaps the most dramatic in human history, the evolution of Chinese income inequality since the start of the reform process in 1978 has been a focus of interest among analysts and policy makers. In their study of the evolution of inequality in China focusing on spatial inequality over the long run, from 1952 to 2000, Kanbur and Zhang (2005) identified two phases of inequality change after the start of reforms in 1978. After an initial short phase of falling inequality as rural incomes rose in the wake of the liberalization of the personal responsibility system, inequality rose inexorably as China opened up to the world and explosive growth took place in the coastal regions.

This increase in inequality became an integral part of the narrative on Chinese development, with some commentators arguing that this was the inevitable price to be paid for the high rates of growth, with others warning of the social consequences of rising gaps. In any event, “harmonious society” was given center stage at the 2005 National People’s Congress and among rising policy concerns on inequality. As more data has accumulated, greater attention has turned to an examination of the evolution of inequality in China in the 2000s, including in the present decade—the years after 2010. This paper attempts to provide a comprehensive assessment of what the data show, a deeper look into the patterns of inequality change, and preliminary explanations for the trends observed. Our basic conclusion is that Chinese inequality appears to be plateauing and, according to some measures, even declining. The explanations lie in policy changes and in the nature of structural transformation in China. We complement our own primary research with a review of the

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recent literature which, we argue, also gives indications towards a turnaround in Chinese inequality.

We then provide a preliminary account of possible explanations of this turnaround in light of Kuznets (1955) and Piketty (2014). Through detailed decomposition analysis of the inequality trends, we relate the turnaround to two classic phenomena in the development economics literature, the Lewis turning point and the Kuznets turning point. We further argue that for China there is evidence that both of these are in turn closely related to government policy changes.

The evolution of inequality as a country grows has been the focus of much analytical and policy discourse at least since the classic work of Kuznets (1955) and his inverse-U hypothesis that inequality would first increase and then decrease with rising per capita income.<sup>1</sup> This focus has stayed strong right up to the present, as exemplified in the blockbuster work of Piketty (2014). Despite Piketty's characterization and critique of Kuznets (1955) as arguing for an inverse-U as a natural law, Kuznets himself did highlight the role of policy when he said: "One group of factors counteracting the cumulative effect of concentration of savings upon upper-income shares is legislative interference and "political" decisions...." (pp 8–9). In other words, for Kuznets (1955) as much as for Piketty (2014), policy matters alongside and in interaction with economic processes, and political economy is integral to the evolution of inequality (see, for example, Acemoglu and Robinson, 2002). We argue in this paper that policy is a key part of the explanation for the evolution of Chinese inequality.

The plan of the paper is as follows. Section 2 sets out the data sources on Chinese inequality on which our assessment is based. Section 3 then presents the basic trends over the 24-year period from 1995 to 2018. Section 4 places our findings in the context of the large literature on Chinese inequality trends, arguing that the dominant narrative of rising inequality has obscured a growing literature pointing to stabilizing of inequality. Section 5 examines the patterns of inequality change by looking, respectively, at decomposition by income source and by population subgroup. Section 6 discusses some preliminary explanations for the observed trends. Section 7 concludes.

## 2. Data

In this study, we use two kinds of data: household-level data from household surveys and provincial-level data from the National Bureau of Statistics (NBS). Household-level data are from two surveys, the Chinese Household Income Project (CHIP) and the China Family Panel Studies (CFPS). CHIP was carried out as part of a collaborative research project on incomes and inequality in China organized by Chinese and international researchers and institutions, including the Institute of Economics of the Chinese Academy of Social Sciences and the School of Economics and Business Administration at Beijing Normal University, with assistance from the NBS. There are six waves of cross-sectional data from CHIP: 1988, 1995, 2002, 2007, 2008, and 2013. CFPS is a nationally representative biennial longitudinal survey of Chinese communities, families, and individuals launched in 2010 by the Institute of Social Science Survey of Peking University. It covers such topics as economic activities, education outcomes, family dynamics and relationships, migration, and health. Currently, there are five waves of panel data from CFPS: 2010, 2012, 2014, 2016, and 2018. Our provincial-level income per capita, consumption per capita, CPI and population data are drawn from the NBS database and multiple provincial statistical yearbooks.

We use household survey data to analyze the evolution of household income inequality and the attributes of different income sources, as these data provide rich information about the various income components in each household. For the analysis of regional inequality evolution and its decomposition, apart from the household survey data, we also make use of the provincial-level data, which provides a long run trend. Each dataset is described below in greater detail.

The household-level data we use are taken from CHIP 1995, 2002, and 2007 (NBS sample) and CFPS 2010, 2012, 2014, 2016, and 2018. We did not go back as far as 1988 because at that time most places in China were still under a command economy, and the income components in the 1988 survey were thus quite different conceptually from those in the later surveys. CHIP 2007 and 2008 are also part of the larger RUMiC (Longitudinal Survey on Rural Urban Migration in China) survey project. While the public RUMiC data were based on a different questionnaire from previous waves of CHIP and have no income component details, CHIP 2007 has a restricted nationally representative NBS sample dataset that is consistent with the previous waves. For this reason, we eliminate CHIP 2008 from our analysis and use only the NBS sample from CHIP 2007.

To analyze income distribution using the two data sets, we need to address data comparability first. For comparability between the two surveys, we take a careful look at income sources asked in each survey. There are some differences between CHIP and CFPS in the coverage of income sources.<sup>2</sup> For example, the rental value of housing equity<sup>3</sup> was included in CHIP 1995 but not in other surveys; medical expenses paid by a collective or the government were included in transfer income in CHIP but not in CFPS, and so on. To ensure as much consistency as possible, we broke down the different sources of income in CHIP and reconstructed them into the same income categories as in CFPS. However, "other income", an item in CFPS survey, was not included in CHIP 2007. We reconstructed it following the CFPS definition.

The difference across waves within each survey is small. The detailed questions about income included in each wave of the CHIP data between 1995 and 2007 are quite consistent. Although there are a few differences in income between CFPS 2010 and later waves,

<sup>1</sup> The hypothesis led to a huge empirical literature and debate. A small selection of papers in this vein is given by Anand and Kanbur (1993), Fields (2001), Banerjee and Duflo (2003), Barro (2008).

<sup>2</sup> For comparison of the two surveys, see Zhang et al. (2014).

<sup>3</sup> This does not refer to the actual rental income, but an imputed value of rent for houses that were not rented out. Actual income from renting out a house was already included in all the surveys.

the CFPS office provides adjusted incomes in CFPS 2012–2018 to make them comparable with CFPS 2010.<sup>4</sup> In addition, we further made a few slight adjustments to make them more consistent over years and between surveys.<sup>5</sup> In the paper, we present two sets of inequality estimates, one based on the original household income from CHIP and CFPS, and the other with adjusted income that is consistent between surveys and across waves.

Another data-related issue we need to address is the missing data and under reporting in income sources. In CFPS, wage income was asked in both household and individual questionnaires except for the wave of 2012. **We defined total household wage income as the maximum of household reported wage and the sum of individual wages.** Unfortunately, due to a technical error, some individual wages were not recorded in 2016. As a remedy, the 2018 wave survey asked respondents to recall their wages back in 2016. Therefore, we could fill the missing individual wage information in 2016 with recalled wages from the CFPS 2018 data when adjusting household wage income. In the absence of questions on household wage income in CFPS 2012, using the sum of individual wage income as a proxy for household wage income may lead to under estimation because not all household members were interviewed and some interviewed might fail to answer the wage question. 6.3% individuals in the national representative sample reported they worked for wage, but wage information is missing. We imputed the missing individual wages in 2012 using random forest algorithm. See Appendix 8 for more detailed discussions on the wage prediction algorithm and results.

In addition to the two issues addressed above, there are some observations for which the sum of all income components exists but does not equal the household net income in CFPS 2014. To deal with this issue, we rescale each income source using the proportion  $\frac{\text{household net income}}{\text{sum of all the income sources}}$ . The average ratios of household net income to the sum of all the comparable components in CFPS is 1 in 2014 and the very small proportion of households whose net incomes are estimated from consumption, the average ratio is 0.94. In CFPS 2012, 4.2% of households did not report any income information. We imputed these households' net income according to their consumption. Due to lack of detailed income sources, in the decomposition analysis, this small proportion of sample could not be used.

Even though the two household surveys both include rich information about household income, their geographical coverage differs. Moreover, CFPS's sampling is only representative in five provinces but not representative in other 20 provinces. Nonetheless, we conducted decomposition exercise by province using the CFPS data for the five representative provinces. But we should bear in mind the limitation of data. In our analysis of regional inequality, we primarily rely on provincial-level income, consumption and population data from the NBS. The two datasets are complementary. The CFPS data have more variations across households within a province, while the regional data provide a longer coverage yet with only average rural and urban income (consumption) in each province.

A major challenge of computing regional inequality with NBS data is the accuracy of population. As Li and Gibson (2013, 2016) have noted, Chinese yearbooks previously reported provincial population and per capita economic outputs based on households registered, that is, the *hukou* population rather than the residential population. This resulted in a distortion of the estimate of provincial per capita statistics in previous research papers. This distortion grew larger as the number of migrant workers increased after the 1990s. Recently, the NBS updated the provincial consumption per capita data based on residential population for all provinces from 1993 to 2017. We also obtain population based on residential status from both NBS and various provincial yearbooks for 2011 and 2005, years in which many provinces updated their historical population data based on residence. The fact that the starting year of reporting residential-based population is different across provinces brings both disadvantages and advantages to our study. On the one hand, the new NBS data though much improved, are still not perfect. On the other hand, there should be no systematic distortion on the aggregate level, as there is no cutoff year in which the statistical approach changed for all. In addition, we use income per capita data from the NBS from 2002 to 2017 to confirm that the pattern of regional inequality based on per capita consumption matches that as measured by income per capita.<sup>6</sup>

This is the data base for our assessment of Chinese inequality trends over the last 24 years. We proceed now to a description of the overall trends and the decomposition patterns in the data.

### 3. Trends

We estimate various inequality measures using household survey data from CHIP and CFPS for eight points of time covering the 24-

<sup>4</sup> For details of the income component adjustment of CFPS, see Xie et al. (2015).

<sup>5</sup> First, we followed the definition of business income as in CFPS 2012–2018 but not the 2010 baseline because self-employment income was not included in 2010 business income. In CFPS 2012–2018, self-employment and private business income were both included in non-agriculture business income, yet they were not separable. Hence when constructing the comparable income, CFPS officially released version excluded all non-agriculture business income. Since private business income is an important income source, such adjustment would under-estimate business income. Therefore, we used the original business income for 2012–2018, instead of the comparable business income as released by CFPS. We first calculated household self-employment income from individual survey questionnaires and then added it to comparable business income in 2010. Second, we excluded donation income in the category of transfer income to match CFPS 2010 and CHIP.

<sup>6</sup> We use provincial consumption per capita as a proxy for provincial income per capita since the NBS income per capita data was not available before 2002. NBS changed their income survey framework and questionnaire in 2013. Thus, the trend of income inequality after 2013 should be explained with caution.

year period between 1995 and 2018. Table 1 presents the Gini coefficient and generalized entropy indices.<sup>7</sup> The results in Panel A of each table use original income per capita, and Panel B reports the results based on adjusted income per capita, which is consistent between the two datasets and across waves for each survey. For both panels, income is deflated using provincial rural and urban CPI. The level of inequality is rather high compared with that of many OECD (Organization for Economic Co-operation and Development) countries and even higher compared with Scandinavian countries but comparable with the other BRICS (Brazil, Russia, India, China, and South Africa) economies.<sup>8</sup> For both income construction methods, we see that the Gini coefficient has an inverted U shape pattern until 2016 with the turning point at 0.525 in 2010. The generalized entropy indices show similar trends. For GE(0), the peak appears in 2012, while for GE(1) and GE(2) it is in 2010. Nevertheless, inequality rebounds to a high level again in 2018. The differences in the turning patterns of each index could be because that each inequality index captures different characteristics of inequality. A more detailed analysis by percentile shares is provided in Appendix 2. The 90–10 income ratio peaks in 2012 and then levels off subsequently. Further sensitivity analysis considering the data comparability issue is provided in the Appendix 3. The overall conclusion is that the time path of inequality, after increasing sharply before 2010, has hit a plateau. Inequality declined after 2010 till 2016, and despite the rebound in 2018 over the last decade it did not go much or at all above the peak of 2010.

The combination of CHIP and CFPS data gives us eight observations spanning the period from 1995 to 2018 based on household surveys. An alternative data perspective, useful for capturing long-term annual trends, was introduced in Kanbur and Zhang (1999, 2005). This method uses NBS data on provincial consumption per capita, broken down by rural and urban areas for each province. Combining this with rural-urban population and CPI data for each province (see the discussion on population data in Section 2), we can construct a synthetic national consumption distribution which suppresses inequality within the rural areas and within urban areas of each province. Clearly, this is an understatement of the level of inequality because within-rural and within-urban variations in a province are masked. But the trend over time may nevertheless convey information on the evolution of inequality, in particular at the regional level.

Fig. 1 presents the Gini coefficient and GE(1), or Theil's T, measure of inequality over time for the synthetic distribution so constructed for every year from 1978 to 2017.<sup>9</sup> The patterns of the two indices are quite similar. They went down slightly after 1978 and began to increase slowly after 1985. In 1996, regional inequality fell slightly and showed a climbing trend until 2004. Of course, the values of the Gini and GE(1) in Fig. 1 are not comparable to the corresponding values in Table 1—income is used in one and consumption in another, within-rural and within-urban inequality is suppressed in one and not in the other, and the data sources are quite different. However, the broad trends after the mid-1990s are similar from the two very different perspectives: inequality appears to peak sometime toward the end of the first decade of the 2000s.

We also present the inequality measures of provincial income per capita in Fig. 2. Provincial income per capita from NBS is not available before 2002. Therefore, our income series covers a shorter period 2002–2017. The trend of regional income inequality from Fig. 2 largely resembles that of regional consumption inequality as shown in Fig. 1.<sup>10</sup> Regional income inequality also shows a clear turnaround.

#### 4. Narratives

Our finding of a plateauing or even turndown of inequality goes somewhat against the dominant narrative of inexorable and sharply rising inequality in China. The rising inequality story was cemented in the early years of the reform process by the perhaps apocryphal quote attributed to Chinese leader Deng Xiaoping—"Let some people get rich first." The narrative has persisted. Thus, to take just one example from the popular press, writing in Forbes magazine Hsu (2016) entitled her article "High Income Inequality Still Festering in China." She quotes Xie and Zhou (2014) and other academics who have calculated a high Gini coefficient for China, comparable to among the highest in the world.

The trends identified in academic studies of the pre-2000 period, for example by Kanbur and Zhang (1999, 2005) and Ravallion and Chen (2007), appear to have shaped views which have been confirmed by other studies of the period. These include, for example, Appleton et al. (2014); Chi et al. (2011); Chi (2012); Goh et al. (2009); Kanbur and Zhuang (2013); Knight (2014); Knight et al. (2016);

<sup>7</sup> The generalized entropy indices are a popular class of measure for inequality. They are derived from information theory as a measure of redundancy in data.  $GE(0) = \frac{1}{N} \sum_{i=1}^N \ln \left( \frac{\mu}{y_i} \right)$ ,  $GE(1) = \frac{1}{N} \sum_{i=1}^N \frac{y_i}{\mu} \ln \left( \frac{y_i}{\mu} \right)$ ,  $GE(2) = \frac{1}{2N\mu^2} \sum_{i=1}^N (y_i - \mu)^2$ , where  $y_i$  is the income of observation  $i$  and  $\mu$  is the mean of income with the distribution  $F(y)$ .

<sup>8</sup> A few examples of Gini coefficients for OECD countries, according to the World Bank, are United States, 0.411 (2013); France 0.331 (2012); Germany 0.301 (2011); and UK, 0.333 (2012). The Gini coefficients for Scandinavian countries are Sweden 0.274 (2012), Norway 0.259 (2012), and Denmark 0.291 (2012). The Gini coefficients for the other BRICS countries are Brazil, 0.527 (2012); Russia, 0.416 (2012); India, 0.352 (2011); and South Africa, 0.634 (2011).

<sup>9</sup> For the exact value of the indices, please see columns 1 and 2 in Table 4.6.

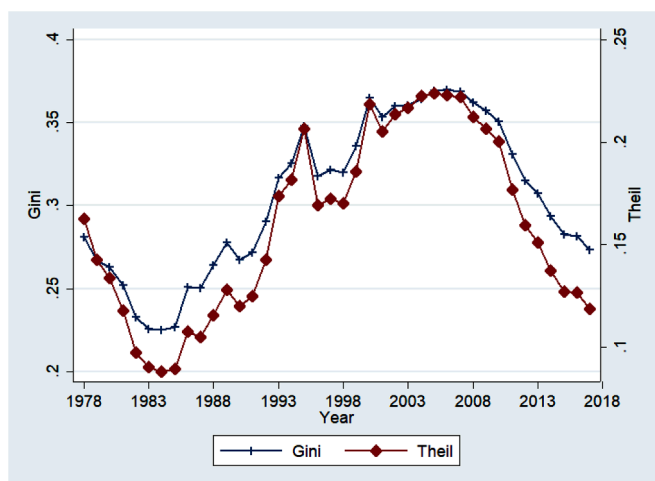
<sup>10</sup> In the presence of consumption smoothing, income inequality should be higher than consumption inequality. However, the figure shows the opposite. This is likely due to the less developed financial market. In rural China, households have to primarily rely their own savings for housing construction and purchase because they do not have the ownership on the residential land, which belong to the villages and cannot be used as collaterals. The sex ratio imbalances in China further intensify the competition in the housing market, forcing households with sons to save more and longer time to build or purchase larger homes (Wei and Zhang, 2011; Wei, Zhang, and Liu, 2017). The lump-sum housing expenditure may be a reason behind the higher consumption inequality relative to income inequality. The difference between the two measures have narrowed in recent years. The spread of e-commerce may have contributed to decline in consumption inequality (Luo, Wang, and Zhang, 2019), as e-commerce disproportionately benefited the residents in rural areas and lagging regions.

**Table 1.**  
Inequality measures from household survey.

A: Original income					
Year	Data	Gini	GE(0)	GE(1)	GE(2)
1995	CHIP	0.437	0.350	0.324	0.428
2002	CHIP	0.459	0.371	0.361	0.490
2007	CHIP	0.439	0.341	0.335	0.467
2010	CFPS	0.522	0.527	0.556	1.469
2012	CFPS	0.501	0.578	0.491	1.008
2014	CFPS	0.500	0.567	0.503	1.987
2016	CFPS	0.508	0.520	0.561	1.732
2018	CFPS	0.521	0.514	0.578	1.872
B: Adjusted income					
Year	Data	Gini	GE(0)	GE(1)	GE(2)
1995	CHIP	0.354	0.211	0.222	0.311
2002	CHIP	0.446	0.345	0.341	0.469
2007	CHIP	0.459	0.374	0.376	0.613
2010	CFPS	0.525	0.538	0.557	1.386
2012	CFPS	0.492	0.556	0.464	0.899
2014	CFPS	0.484	0.542	0.428	0.702
2016	CFPS	0.476	0.463	0.435	0.840
2018	CFPS	0.520	0.592	0.502	0.858

Note: Panel A uses the original income from each survey. Panel B adjusts Chinese Household Income Project (CHIP) income with the same income components in CFPS. CHIP 2007 uses data from the National Bureau of Statistics (NBS) survey rather than the Longitudinal Survey on Rural Urban Migration in China (RUMiC) survey, because the latter uses a different questionnaire and sample framework while the former is consistent with previous years. CHIP 2002 uses a larger NBS sample than the public available dataset. For all the tables in this paper, income is deflated to the real term.

Source: Authors' calculation based on CHIP and CFPS data.



**Fig. 1..** Regional inequality in consumption per capita

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

[Mendoza \(2016\)](#). In their recent comprehensive assessment, [Piketty, Yang and Zucman \(2017\)](#), conclude that: “income inequality has increased substantially since the beginning of the reform process. China used to be more equal than Europe in the late 1970s—about as equal as the most egalitarian Nordic countries—while it is now approaching U.S. inequality levels” (p. 34).

And yet, although our study conducts a comprehensive analysis using different data sources, a number of other studies using a range of data sources and methods, have in recent years been noticing, little by little, a shift in the trend of inequality. Chinese inequality did indeed rise dramatically after the start of reforms and is now one of the highest in the world, but it is no longer increasing anywhere near as sharply as in the past, and there may indeed be a plateauing and, in some studies, a turnaround.

[Zhang \(2016\)](#) noted that “Since 2008, overall pay inequality has decreased, with between-province and between-sector inequality both showing steady declines.” [Zhang et al. \(2011\)](#) argued that “China has reached the Lewis turning point” meaning by this that rural labor markets had begun to tighten and rural incomes to rise relative to urban incomes. These points were also picked up in the popular press, for example by [Bullock \(2017\)](#) in *Forbes Magazine*. A number of studies have looked at post 2000 data and have begun to change our perception of inequality evolution in China. These include, for example, [Khan and Riskin \(2005\)](#); [Fan et al. \(2011\)](#); [Li et al. \(2016\)](#);

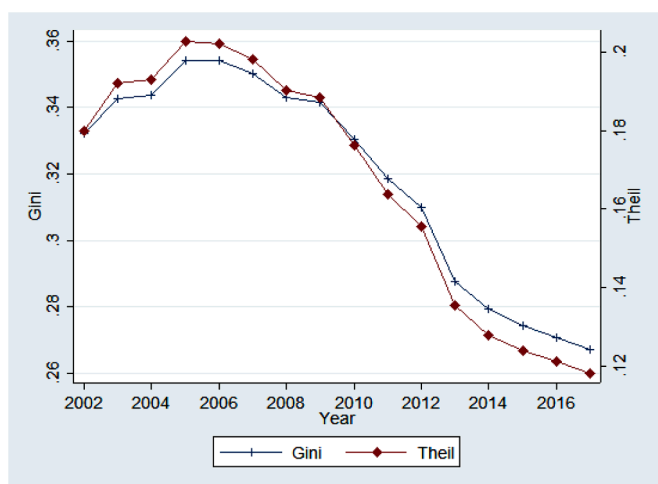


Fig. 2.. Regional inequality in income per capita

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

Alvaredo et al. (2017); Chan et al. (2014); Li and Gibson (2013); Lee (2013); Cheong and Wu (2014); Zhang (2015); Xie and Zhou (2014); Xie et al. (2015); Zhang (2016). The issue was raised as a possibility but not explored by Knight (2014) in his review. In their overview of Chinese development, Fan et al. (2014) conclude: "Although China's income inequality remains at a globally high level, at least the worsening trend seems to have been reversed." (p. 10).

Perhaps most striking is the paper by Piketty, Yang, and Zucman (2017) referred to above, whose headline conclusion has been summarized above. However, the conclusion applies to the overall trend, comparing the start of the reform process to today. But their data also (Figure 10) show the income share of the top 1% stabilizing and perhaps declining a little after 2010. Further, their analysis also shows that the wealth share of the top 10% rose sharply but has stabilized in the last decade.

Most recently, the survey by Zhang (2020), which refers to an earlier working paper version of our paper, also points to other papers in the literature which indicate a possible downturn in inequality, while still emphasizing the increasing inequality phase. Compared to his paper we: (i) have the latest trend until 2018; (ii) use a consistent data source to measure inequality rather than cite different estimates from different studies so that it is comparable over time; (iii) present a more detailed discussion about possible institutions and factors that may affect inequality in the appendix (land rental, real estate, transfer income mistargeting, etc.); (iv) document within region (rural/urban) inequality which is not presented in that paper; (v) have a more comprehensive discussion about decomposition results; and (vi) have solved several problems associated with data: residential population instead of hukou population in NBS data, and random forest methods to predict missing income in CFPS.

A comprehensive listing of studies on Chinese inequality trends is provided in Table A1. Against the backdrop of the dominant rising inequality narrative, one consequence of the piecemeal development of findings on stabilizing or falling inequality in China is that there is limited exploration of the possible mechanisms whereby inequality has been mitigated. We begin this exploration in the next section by examining the patterns of inequality change through decomposition analysis.

## 5. Patterns

Overall, then, a careful assessment of the best data sources seems to suggest a plateauing of overall income inequality, with a possible turning point of regional inequality around the first decade of the new millennium. To begin building an explanation of the trend, we decompose inequality by income sources and population groups.

### Decomposition by income source

To understand the role of different income sources in the evolution of overall inequality, we decompose the Gini coefficient by income source following Lerman and Yitzhaki's (1985) rule.

$$G = \sum_k S_k \sum_i \frac{2}{n^2 \mu_k} \left( i - \frac{n+1}{2} \right) Y_{ki} = \sum_k S_k \bar{G}_k = \sum_k S_k R_k G_k, \quad (1)$$

where  $S_k = \mu_k / \mu$  is the share of  $k$ th income component in total income,  $\bar{G}_k$  is the "pseudo-Gini,"<sup>11</sup>  $R_k$  is the Gini correlation of component

<sup>11</sup> The pseudo-Gini is different from the conventional Gini because the weight attached to  $Y_{ki}$  corresponds to the rank of individual  $i$  in the total income distribution, which is, in general, not the same as his or her rank in the distribution of income source  $k$ .



k with total income, and  $G_k$  is the Gini of income component k. The absolute contribution of income source k to total income inequality is

$$v_k(G) = S_k R_k G_k. \quad (2)$$

Its proportion of the total inequality is

$$\tilde{v}_k(G) = \frac{S_k R_k G_k}{G} = \frac{\sum_i \left(i - \frac{n+1}{2}\right) Y_{ki}}{\sum_i \left(i - \frac{n+1}{2}\right) Y_i}, \quad (3)$$

where  $Y_i$  is the income of household i and  $Y_{ki}$  is the income from source k of household i.<sup>12</sup>

The marginal effect of income source k is

$$\eta_k(G) = S_k \left( \frac{\bar{G}_k}{G} - 1 \right). \quad (4)$$

Table 2 shows the share of income by source and Table 3 presents the Gini coefficient of each income source. Wage income represents the largest share, while its Gini coefficient is the smallest. The share of property income was small, at less than 4 percent, throughout the period under study, while its Gini coefficient was very high and remained above 0.95. The Gini correlation,  $R_k$ , proportionate contribution to the total Gini coefficient of each income source,  $\tilde{v}_k(G)$ , and its marginal effects,  $\eta_k(G)$ , are reported in Tables 4, 5, and 6, respectively. The largest contribution is from wage income, which ranged between 66 percent and 79 percent over the years, followed by business income and transfer income, which ranged from 2 percent to 16 percent and from 9 percent to 18 percent, respectively. The contributions of property income and other income source are in general less than 6 percent. In addition to its high contribution to the overall Gini coefficient, wage income and business income have higher marginal effect than other three sources of income.

Given the importance of wage income, the trends shown in Table 3 are central in understanding the forces underlying the overall inequality trend. Inequality of wage income has largely fallen during the period, as has inequality of transfers. As they are the important factors in total income, the decline in inequality in these two income sources plays a key role in shaping overall inequality. Appendix 4 conducts a similar analysis for the Theil index of inequality.

In addition to the level of inequality, the change in inequality over time can also be expressed as a weighted average of over time changes in each income source, as stated in Paul et al. (2017). Denote  $\dot{G}_{t,t+1} = (G_{t+1} - G_t)/G_t$ , which is the proportionate change in household income inequality between year t and year t + 1. It could be written as

$$\dot{G}_{t,t+1} = \sum_k \tilde{v}_k(G_t) \dot{v}_k(G_{t,t+1}), \quad (5)$$

where  $\tilde{v}_k(G_t)$  serves as a weight, and  $\dot{v}_k(G_{t,t+1}) = \frac{v_k(G_{t+1}) - v_k(G_t)}{v_k(G_t)}$ . Then the contribution of income source k to the change in the Gini coefficient is  $\tilde{v}_k(G_t) \dot{v}_k(G_{t,t+1})$ . Similar decomposition rules apply to the Theil index as well, whose results are given in Appendix 3.

The results for decomposition of the change in inequality are presented for the Gini in Table 7 and for the Theil in Appendix Table A4.3. The greatest contribution to the proportionate increase of the Gini coefficient from 1995 to 2002 was wage income. During the sample period, wage income contributed to the change in Gini coefficient in the same direction except for the periods 2002–2007 and 2012–2014. During the period 2002–2012, business income enlarged overall inequality, while transfer income played an offsetting role. Interestingly, the direction of forces from business income and wage income tends to be opposite.

Inequality increased from 2016 to 2018. The key driver is rising wage inequality during the period. However, we should interpret the decomposition on the change in Gini from 2016 to 2018 with caution since the recalled wage in 2016 may not be accurate.

Overall, then, these accounting exercises are consistent with the hypothesis that it is the narrowing of the wage distribution and the role of transfers that are important in beginning an understanding of the overall trend of Chinese inequality.

Finally, we note that income inequality is of course not the same concept as wealth inequality. Chinese households' wealth is mainly invested in real estate. According to China Livelihood Development Report 2014, housing asset takes about three quarters in Chinese household wealth, and as housing price rises, wealth inequality can be higher than income inequality.<sup>13</sup> More discussion about the role of overinvestment in real estate and house rental income is provided in Appendix 7.

### Decomposition by subgroups

An alternative perspective on patterns of inequality change is provided by decomposition by population subgroup. Unequal income distribution between urban and rural sectors is a common feature in developing countries, and China is no exception. In addition to the

<sup>12</sup> We weighted household income by family size in all calculations.

<sup>13</sup> The wealth Gini estimated from CFPS 2012 is as high as 0.73 (China Livelihood Development Report 2014).

**Table 2.**

Share of income by source comparable income (real).

Year	Wage income	Business income	Property income	Transfer income	Other income
1995	0.502	0.375	0.010	0.074	0.041
2002	0.578	0.237	0.008	0.121	0.056
2007	0.603	0.206	0.034	0.146	0.011
2010	0.692	0.156	0.023	0.089	0.042
2012	0.665	0.176	0.021	0.101	0.037
2014	0.689	0.155	0.019	0.113	0.024
2016	0.724	0.138	0.017	0.095	0.026
2018	0.723	0.127	0.020	0.107	0.023

Note: To be as consistent as possible across the two datasets, we excluded some components from the Chinese Household Income Project (CHIP) that are not in the China Family Panel Studies (CFPS) survey and add back components not included in CHIP but in CFPS. In addition, the income sources are recalculated in CHIP according to CFPS definitions. Wage income is labor income including bonuses, allowances and subsidies, and remittances from migrant worker family members. Business income includes net income from the sale of farm products, net income from private enterprises and self-employment, and gross value of self-consumption of farm products. Property income is income from rental or sales of properties. Transfer income includes social security, pension, subsidies, etc. Other income is mainly money and gifts from relatives or friends.

Source: Authors' calculation based on CHIP and CFPS data.

**Table 3.**

Gini coefficient of income by source.

Year	Wage income	Business income	Property income	Transfer income	Other income
1995	0.690	0.575	0.953	0.927	0.810
2002	0.656	0.633	0.981	0.900	0.811
2007	0.628	0.730	0.967	0.858	0.907
2010	0.583	0.797	0.983	0.925	0.909
2012	0.586	0.827	0.968	0.901	0.949
2014	0.581	0.848	0.964	0.861	0.961
2016	0.518	0.866	0.961	0.871	0.965
2018	0.572	0.899	0.957	0.864	0.982

Note: Each income source follows the same definition as in Table 2.

Source: Authors' calculation based on CHIP and CFPS data.

**Table 4.**

Gini correlation by source.

Year	Wage income	Business income	Property income	Transfer income	Other income
1995	0.809	0.059	0.684	0.600	0.450
2002	0.859	0.049	0.699	0.737	0.620
2007	0.836	0.236	0.724	0.629	0.656
2010	0.910	0.473	0.803	0.710	0.607
2012	0.839	0.539	0.586	0.596	0.549
2014	0.851	0.507	0.624	0.568	0.453
2016	0.883	0.638	0.623	0.534	0.581
2018	0.893	0.594	0.620	0.588	0.739

Note: Each income source follows the same definition as in Table 2.

Source: Authors' calculation based on CHIP and CFPS data.

**Table 5.**

Contribution to total Gini coefficient by source (Percent).

Year	Wage income	Business income	Property income	Transfer income	Other income
1995	78.95	3.56	1.78	11.53	4.18
2002	72.90	1.65	1.27	17.91	6.27
2007	68.61	7.72	5.15	17.10	1.42
2010	69.97	11.20	3.38	11.07	4.38
2012	66.10	16.29	2.44	11.20	3.98
2014	70.36	13.80	2.29	11.42	2.12
2016	69.50	16.04	2.10	9.30	3.05
2018	71.06	13.05	2.24	10.49	3.16

Note: Each income source follows the same definition as in Table 2.

Source: Authors' calculation based on CHIP and CFPS data.



**Table 6.**  
Marginal effect by source.

Year	Wage income	Business income	Property income	Transfer income	Other income
1995	0.288	−0.339	0.008	0.042	0.001
2002	0.151	−0.221	0.004	0.059	0.007
2007	0.084	−0.129	0.018	0.025	0.003
2010	0.008	−0.044	0.011	0.022	0.002
2012	0.001	−0.016	0.003	0.010	0.002
2014	0.014	−0.017	0.005	0.001	−0.002
2016	−0.029	0.022	0.004	−0.002	0.005
2018	−0.013	0.004	0.003	−0.003	0.009

Note: Each income source follows the same definition as in Table 2. Marginal Effect is the impact that a 1% change in the respective income source will have on inequality.

Source: Authors' calculation based on CHIP and CFPS data.

**Table 7.**  
Contribution to the change of Gini (Percent).

Year	Gini Change (%)	Wage Income	Business Income	Property Income	Transfer Income	Other income
1995–2002	25.96	12.87	−1.48	−0.18	11.03	3.72
2002–2007	2.96	−2.26	6.30	4.03	−0.30	−4.81
2007–2010	14.36	11.41	5.09	−1.29	−4.44	3.59
2010–2012	−6.29	−8.03	4.07	−1.09	−0.58	−0.65
2012–2014	−1.47	2.01	−2.12	−0.05	0.46	−1.86
2014–2016	−1.68	−2.03	1.97	−0.23	−2.28	0.88
2016–2018	9.18	8.08	−1.79	0.35	2.15	0.40

Note: Each income source follows the same definition as in Table 2.

Source: Authors' calculation based on CHIP and CFPS data.

unequal development between rural and urban regions, the disparity between the coastal areas in the east and inland areas in the middle and west is also enormous (Fan et al., 2011). To understand these components of inequality, we use the data underlying Tables 8 and 9, the synthetic distribution constructed from rural and urban per capita consumption, income, and population.

We further decompose the Theil's T index by rural-urban subgroups and coastal-inland subgroups, respectively, as in equation (10).

$$T = T_w + T_b = \sum_k \left( \frac{N_k}{N} \right) \frac{\mu_k}{\mu} T_k + \sum_k \frac{N_k}{N} \frac{\mu_k}{\mu} \ln \left( \frac{\mu_k}{\mu} \right) = \sum_k \frac{Y_k}{Y} T_k + \sum_k \frac{Y_k}{Y} \ln \left( \frac{Y_k}{Y} / \frac{N_k}{N} \right), \quad (6)$$

where N is the total number of individuals and k is an indicator for groups, for example, rural or urban. The first term is the within-group component of the Theil's T index and the second term is the between-group component.

The rural-urban between component and the coastal-inland between component of consumption inequality are reported in Table 8 and graphed in Fig. 3. And the between components of income inequality are reported in Table 9 and graphed in Fig. 4. The long-term trend of regional consumption inequality shows that there are three peaks for the rural-urban between component, in 1995, 2000, and 2004. After the third peak, the rural-urban between component maintained a declining trend. the trend of regional income inequality since 2002 also shows the same pattern with the peak at 2005. Notice that both regional inequality and rural-urban between components as measured with income and consumption turned downward the mid-2000s. That is the time when, it has been argued, China passed the “Lewis turning point” (Zhang et al., 2011). That is also the time when the agriculture tax was completely abolished and the New Countryside Project was initiated.<sup>14</sup> The coastal-inland between component of regional consumption inequality fell in 2001 after a high peak in 2000 and then jumped again in 2005. It remained at a relatively high level until 2009 and then showed a steady decline, same as the trend of regional income inequality, contributing to the narrative of tightening labor markets in inland provinces and government policy to encourage development in the western regions. These explanations are taken up in the next section.

We observe that between-region inequality has kept declining in the past several years, while within-region inequality (in particular, within rural and urban) has leveled off or even slightly increased in the last two years of the sample period as shown in Figs. 5 and 6. Given the aggregate data includes only average per capita consumption and income for rural and urban residents in each province, the within rural-urban inequality masks the large potential variations within a province. To check this point, we decompose CFPS inequality by province as shown in Table 10.<sup>15</sup> We find that the between region components kept a declining trend with slight fluctuations, in line with the trend of regional inequality based on aggregate per capita consumption (income) data. By contrast, the within region components slightly increased between 2010 and 2018. This is probably why the trend of household inequality and

<sup>14</sup> Nationwide abolishment of the agriculture tax started in January 2006. The New Countryside Project was initiated in October 2005.

<sup>15</sup> To perform decomposition by provinces, we keep all the samples in the 5 provinces sampling framework, which are representative at the provincial level.

**Table 8.**

Regional consumption inequality and inequality between components.

Year	Gini	Theil	Rural-Urban	Coastal-Inland
1978	0.281	0.162	0.147	0.002
1979	0.267	0.143	0.127	0.003
1980	0.263	0.134	0.117	0.004
1981	0.252	0.118	0.1	0.004
1982	0.233	0.097	0.079	0.005
1983	0.226	0.091	0.072	0.004
1984	0.225	0.088	0.07	0.004
1985	0.227	0.09	0.073	0.004
1986	0.251	0.108	0.084	0.006
1987	0.251	0.105	0.082	0.006
1988	0.264	0.116	0.088	0.009
1989	0.278	0.128	0.098	0.009
1990	0.267	0.12	0.095	0.008
1991	0.272	0.125	0.098	0.007
1992	0.291	0.143	0.112	0.01
1993	0.316	0.174	0.14	0.012
1994	0.325	0.182	0.136	0.018
1995	0.348	0.207	0.156	0.028
1996	0.318	0.169	0.124	0.018
1997	0.322	0.173	0.129	0.018
1998	0.32	0.17	0.129	0.016
1999	0.336	0.186	0.143	0.016
2000	0.365	0.218	0.173	0.03
2001	0.353	0.205	0.16	0.019
2002	0.36	0.213	0.164	0.021
2003	0.361	0.217	0.167	0.021
2004	0.365	0.222	0.175	0.02
2005	0.369	0.224	0.181	0.04
2006	0.37	0.223	0.178	0.043
2007	0.368	0.222	0.176	0.042
2008	0.362	0.212	0.168	0.041
2009	0.357	0.206	0.163	0.041
2010	0.35	0.2	0.158	0.038
2011	0.331	0.177	0.137	0.034
2012	0.315	0.159	0.123	0.032
2013	0.307	0.151	0.113	0.031
2014	0.294	0.137	0.098	0.03
2015	0.282	0.127	0.087	0.028
2016	0.282	0.127	0.081	0.031
2017	0.273	0.119	0.073	0.030

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

**Table 9.**

Regional income inequality and inequality between components.

Year	Gini	Theil	Rural-Urban	Coastal-Inland
2002	0.332	0.180	0.142	0.021
2003	0.343	0.192	0.153	0.021
2004	0.344	0.193	0.154	0.021
2005	0.354	0.203	0.164	0.039
2006	0.354	0.202	0.164	0.039
2007	0.350	0.198	0.163	0.036
2008	0.343	0.190	0.158	0.033
2009	0.341	0.188	0.156	0.033
2010	0.330	0.176	0.146	0.033
2011	0.318	0.164	0.135	0.030
2012	0.310	0.156	0.128	0.028
2013	0.288	0.136	0.111	0.022
2014	0.279	0.128	0.104	0.021
2015	0.274	0.124	0.100	0.020
2016	0.271	0.121	0.097	0.019
2017	0.267	0.118	0.094	0.019

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

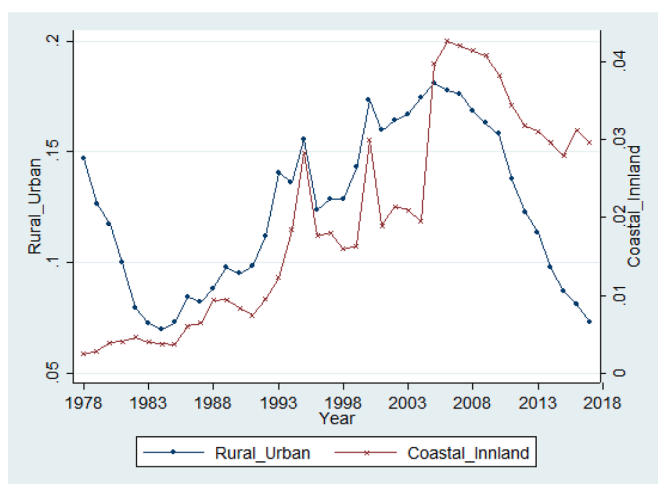


Fig. 3.. Between component of consumption GE(1)

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

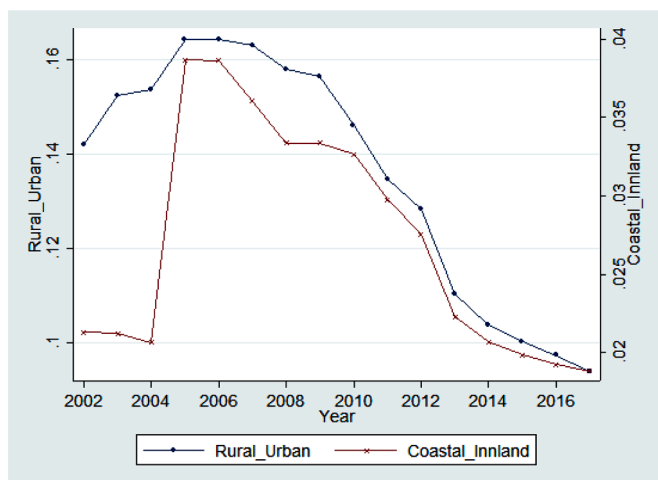


Fig. 4.. Between component of income GE(1)

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

regional inequality measures diverge in recent years.

A final point on levels and trends of inequality. When comparing regional inequality as measured with income per capita and consumption per capita, we have an interesting observation. The aggregate data shows that regional consumption inequality is higher than regional income inequality as shown in Fig. 7 and 8. This is a little surprising since usually consumption inequality should be lower with the presence of consumption-smoothing mechanisms. Nevertheless, since 2012, the two inequality measures have converged. And the convergence coincides with rapid spread of E-commerce in China, which may reduce consumption inequality (Luo et al., 2019).<sup>16</sup> This suggests that the discrepancy between income inequality and consumption inequality may reflect market access problem for consumers in remote area. Of course, a full explanation on the discrepancy belongs to another paper.

<sup>16</sup> Luo et al. (2019) found that the spread of E-commerce commerce promoted consumption in rural areas and lagging regions, which may reduce regional consumption inequality, suggesting that the market access channel may be at play in the puzzle. Another explanation is lump-sum expenditure of housing construction in rural areas. In rural areas, people have to save for a long time to build a new home due to lack of credit market and property rights for rural residential land (Wei and Zhang, 2011; Wei, Liu, and Zhang, 2017). Such lump-sum expenditure is likely a contributing factor to high consumption inequality.

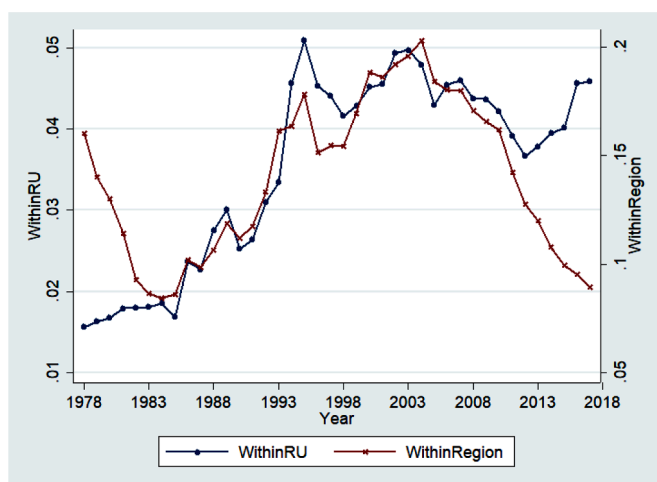


Fig. 5. Within component of regional consumption GE(1)

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

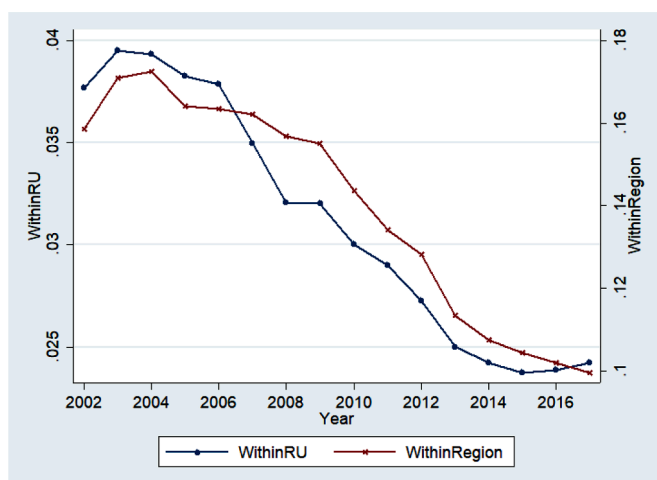


Fig.6.. Within component of regional income GE(1)

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

**Table 10.**  
Decomposition by region of household income GE(1).

Year	Within province	Between province
2010	0.427	0.165
2012	0.434	0.081
2014	0.348	0.110
2016	0.434	0.081
2018	0.442	0.109

Source: Authors' calculation from CFPS.

## 6. Explanations

Our main task in this paper has been to establish the key trends in Chinese inequality over the past several decades. Based on a number of perspectives, it does seem as though there was a turnaround in Chinese inequality about 10 years ago, with inequality plateauing and, according to some measures, even declining after a long period of sharp increase. Explanations for this evolution will have to await detailed investigation from researchers focusing on a range of factors in depth. However, in this section we present a broad framework for such explanations.

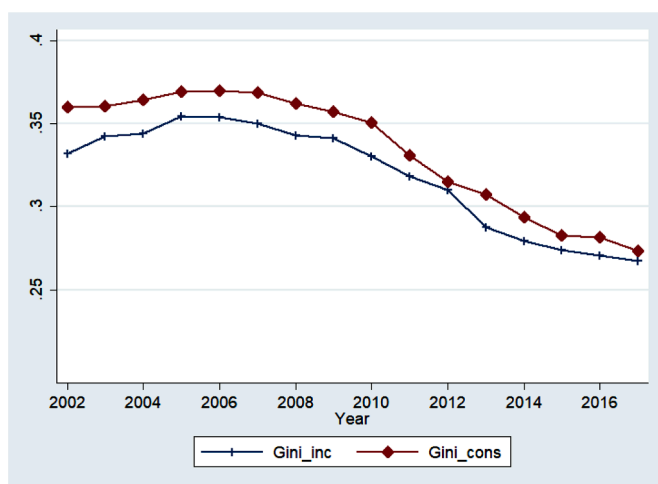


Fig. 7.. Regional consumption and income Gini

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

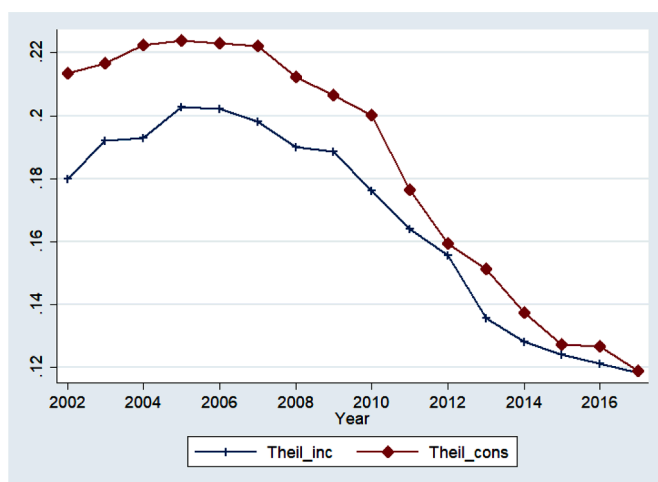


Fig. 8.. Regional consumption and income Theil

Source: Authors' calculations based on data from the National Bureau of Statistics and various provincial statistical yearbooks.

A simple way to think of the evolution of national income distribution is to divide the economy up into key sectors and to look at inequality within and between sectors. Given the importance of the structural transformation, which is under way in China just now, we can begin our discussion in terms of two sectors—rural and urban. The national income distribution is a weighted sum of the rural income distribution and the urban income distribution, with the weights being the population shares of the two sectors. Overall inequality will then depend on (1) the inequality within each of the two sectors, (2) the gap between the means of the two sectoral distributions, and (3) the population share of each sector.

As an illustration, for the GE(0) index, also known as the mean log deviation, denoted  $L$ , national inequality can be decomposed as follows:

$$L = x L_1 + (1-x)L_2 + \log [x k + (1-x)] - [x \log (k)], \quad (7)$$

where subscripts 1 and 2 denote rural and urban, respectively;  $x$  is the population share of the urban sector; and  $k$  is the ratio of the urban mean to the rural mean. The evolution of national inequality is then composed of (i) the evolution of  $L_1$  and  $L_2$ , (ii) the evolution of  $k$ , and (iii) evolution of  $x$ .

With this framework, we can relate the inequality turnaround to basic economic forces and to policy. Gollin (2014) addresses the question of the Lewis turning point in his 60-year perspective on the Lewis model:

“At some point, assuming that population growth did not outpace the accumulation of capital, sufficient labor would be pulled out of the subsistence sector to drive that part of the economy into a neoclassical mode of operation in which wages would be driven

upwards by a rising marginal product of labor. For Lewis and his subsequent expositors, this moment represents a turning point.” (p. 84)

This turning point has played an important role in the development discourse, for example on whether East Asia growth in the 1960s was sustainable once cheap labor from rural areas had been exhausted (Young, 1995).

Some researches argue that China has passed the Lewis Turning point with wage convergence as the evidence (Cai and Du, 2011; Liu, 2015; Zhang et al., 2011). As rural-to-urban migration begins to tighten rural labor markets and hereby mitigate the rural-urban wage differential. While other researches reckon that China has not reached the Lewis Turning point given the existence of large labor stock in rural area according to official statistics. China's unique institutional and policy-induced barriers to migration have prevented many rural workers from migrating to cities, thus raising urban unskilled wages (Golley and Meng, 2011). In addition, heavy government investment in infrastructure in the rural sector and in lagging regions, a feature of Chinese policy from the 2000s onward (Fan et al., 2011), will also raise economic activity and incomes in these areas.<sup>17</sup> This will surely lower  $k$  in Eq. (7) and hence, *ceteris paribus*, overall inequality.

One implication of the Lewis turning point is that the between group component of the inequality decomposition, showing the contribution of rural-urban differential to overall inequality, will fall. This is consistent with the trend decline of the rural-urban component of inequality in the 2000s, shown in Tables 8, 9 and Figs. 3, 4. It is further consistent with the observed reduction in inequality in the national wage distribution as shown in Table 4.2.

The narrowing of the wage distribution and the increasing equality of the transfer distribution shown in Table 3 can also be associated with policy changes. For example, in 2004 the Ministry of Labor and Social Security issued a “Minimum Wage Regulations” law and the next decade saw rising minimum wage standards coupled with substantial improvements in compliance (Li et al., 2018). Further, a number of social programs were introduced and strengthened from the 2000s onward. Since 2004, for example, China has introduced new rural cooperative medical insurance, currently covering more than 95 percent of the rural population. Rural social security has also been rolled out since 2009. Although the benefits for rural medical insurance and social security are still much lower than their urban counterparts, the programs have provided some cushion to rural residents against health risk and elderly care. Tightening labor markets in rural areas, combined with inequality-mitigating transfer and regulation regimes in urban and rural areas, acted through channels (i) and (ii) to reduce inequality.

The impact of  $x$  on  $L$ , as seen through Eq. (7), is quite complex. With all other factors constant, it can be shown (Kanbur and Zhuang 2013) that under certain conditions the behavior of  $L$  as a function of  $x$  has an inverse-U shape, as hypothesized by Kuznets (1955). Up to a certain point, urbanization increases inequality, and beyond this point further urbanization will decrease inequality. This “Kuznets turning point” sets out the effect of urbanization pure and simple on inequality. This phenomenon was recognized some time ago, for example by Robinson (1976). The turning point itself depends on the other inequality parameters, but it is shown by Kanbur and Zhuang (2013) that Chinese urbanization has now crossed the Kuznets turning point—and further urbanization will reduce inequality through channel (iii) above.

These explanations may also apply to other countries with fast growth rate, high level of inequality with a reversing trend. For example, in Brazil, narrowing gaps between the informal and formal sectors and urban and rural sectors, together with safety net expansion covering health care, education and minimum wage regulation all contributed to reduction in inequality.<sup>18</sup> Of course, each of these potential explanations needs to be investigated more fully and in greater depth. But they appear to us to be consistent with underlying economic and policy forces which can explain the inequality turnaround we see in the data.

## 7. Conclusion

We have argued in this paper that, contrary to the dominant narrative, the long period of inequality increase in China may be coming to an end. Using multiple data sources, our paper argues that Chinese inequality is experiencing a turnaround—a plateauing in general and according to some measures, even a decline. In our survey of the literature, we argue that there have been harbingers of this turnaround, but it has not been systematically explored nor given the prominence it deserves. Our review thus consolidates the literature indicating a turnaround, and provides empirical foundations for it. The data, seen from different perspectives, seem to indicate a turnaround towards the latter part of the first decade of the 2000s.

The paper also relates the turnaround to two “turning points” in the development economics literature, the Lewis turning point and the Kuznets turning point. These explanations for the turnaround need to be explored further, but there is *prima facie* evidence of economic forces and government policy leading to tightening labor markets in rural areas, together with government transfers and social policy mitigating inequality in urban and rural areas, which may explain the observed trends. There is therefore no inexorable law linking inequality and growth. Rather, policy matters, as both Kuznets (1955) and Piketty (2014) have argued. Further, not only is the trend of inequality important for China itself but, given its large population weight, this trend also dominates the “within-country” component of global inequality as set out for example in Lakner and Milanovic (2016).

Thus our findings contribute to the general development economics literature on the relationship between inequality and economic

<sup>17</sup> Christiaensen et al. (2013) study the poverty reduction in two rural lagging areas, Gannsu and Inner Mongolia during 2000–2004. They find that rising labor productivity in agriculture has been key in understanding income increase for poor rural households in these areas when non-agriculture drives national growth. For example, agriculture income took 27% of total rural household income in Gansu and 71% in Inner Mongolia. Government policy that improved investment in infrastructure and subsidized agriculture could further raise agriculture productivity in lagging areas.

<sup>18</sup> See discussions in “Poverty and Shared Prosperity Report: Taking on Inequality”, World Bank, 2016.



development, quite apart from the importance of China as a developing economy. For China, the narrative needs now to accommodate a turnaround in inequality, and needs to focus on the reasons for this turnaround. The turnaround also raises the further question of why government policy changed over a 20-year period from allowing inequality to increase to mitigating it. The political economy of the Chinese state (Wong, 2011) may provide an explanation, but that takes us beyond our present remit. Although China's inequality has come to a plateau, the level is still very high compared with many countries. More efforts are still needed to keep the momentum in mitigating the forces for rising inequality.

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## Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.jce.2020.10.001](https://doi.org/10.1016/j.jce.2020.10.001).

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