Study on comparison of the advantages of different soybean producing areas in China from a temporal and spatial perspective

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Abstract. As one of the important oil crops in China, soybean plays a significant place in the national food security system. This article analyzes the comparative advantages of soybean producing areas in China and further divides the advantage of soybean production into the advantage of scale and the advantage of efficiency. In addition, it adopts the advantage index to objectively describe the advantageous areas of soybean production and the comparison of scale advantage and efficiency advantage in these areas since 1978. Through the research, the article obtains the following findings: (1) Since the Reform and Opening Up, scale advantage has still been the determinant to the soybean production advantages of an area. While soybean production has been even more concentrated in soybean producing areas of Heilongjiang and Inner Mongolia, the efficiency advantage index in these two provinces has not been improved in the same pace. (2) The status of efficiency advantage has been constantly rising in other producing areas with the most comparative advantage (other than Heilongjiang and Inner Mongolia) and those with the least comparative advantage. The disadvantageous producing areas have gradually bettered the suitability of soybean production through breeding of fine varieties and high-quality cultivation. (3) The disadvantageous soybean producing areas can become the advantageous areas of soybean production depending on efficiency advantage, and the soybean producing areas with scale advantage can further improve their efficiency of soybean planting. This research provides a scientific reference for the regional deployment of soybean planting in China as well as a scientific basis for policy making.

1. Introduction
Being the country of origin of soybean, China was once the biggest soybean producer of the world [1]. In ancient times, soybean was widely planted and mainly distributed in the middle reaches of the Yellow River, Northeast China and the middle and lower reaches of the Yangtze River. By the first century BC, the planting area of soybean accounted for 2/5 of the total crop area. By modern times, China’s soybean yield occupied 80% of the total soybean yield worldwide and was undoubtedly the...
biggest soybean producer of the world; and at that time, soybean was mainly produced in Northeast China, where the planting area took up 1/3 of the total sown area of major crops in China. After the founding of new China, particularly since the Reform and Opening Up, all Chinese provinces have been exposed to various changes of soybean production and exhibited new features [2]. All regions except Qinghai are planting soybean, mainly including the one-crop-a-year spring soybean area in the north (spring soybean area in the northeast, spring soybean area in North China, spring soybean area in the northwest loess plateau and irrigated spring soybean area in the northwest), the summer soybean area in the Huang-Huai-Hai Basin (spring and summer soybean in middle Hebei and Shanxi and summer soybean in the Huang-Huai-Hai Basin), summer soybean in the Yangtze River Basin (summer soybean in the Yangtze River Basin and summer soybean in the Yunnan-Guizhou Plateau), spring, summer and autumn soybean in the southeast and four-season soybean area in South China [3]. In this article, the soybean production in a province is considered as the result of the planting area and the yield per unit area. The soybean planting area embodies the national policy, the farmers’ willingness of planting and the cost benefit of soybean production, while the yield per unit area reflects the resource endowment of the soybean producing area, the growth cycle, the weather conditions, the level of science and technology-supported breeding and the fine varieties cultivation technology and so on [4-10].

In the 1980s, Pan Tiefu et al. divided the soybean producing areas in China into 6 climatic zones and 20 climatic regions according to the climatic and ecological conditions for soybean production, the distribution of climatic resources in China and the system and distribution of soybean production at that time [11]. In the 1990s, Zhu Wenying et al. researched on the ecotype and ecological division of soybean in Zhejiang Province based on the climatic conditions and the cropping system of Zhejiang Province [12]. By the end of the 20th century, Tian Peizhan et al. investigated the division of soybean varieties in Jilin Province in details [13]. In the early 2000s, Wei Jianjun et al. discussed the regional division and introduction of soybean in Xinjiang combining the climatic conditions of Xinjiang [14]. In 2014, Zhang Xia et al. researched on the high-yield cultivation of summer soybean in HuaiBei Area based on the meteorological conditions there [15]. In 2018, Wang Yanping et al. studied on the climate suitability of soybean in the northeast of Inner Mongolia and explored the regional division of soybean production considering the suitability based on GIS [16]. In 2019, Wang Honglei and Yuan Zihan et al. analyzed the rejuvenation and development path of the soybean industry in China under the soybean rejuvenation plan [17-18]. This article will analyze the comparative advantage of various soybean producing areas in China, divide the advantage of soybean production into scale advantage and efficiency advantage, and adopt the advantage index to objectively describe the advantageous areas of soybean production and the comparison of scale advantage and efficiency advantage in these areas since 1978, thus to provide a scientific reference for the regional deployment of soybean planting in China as well as a scientific basis for policy making.

2. Method of comparative advantage analysis for soybean producing areas

The changes of soybean producing areas are associated with the comparative advantage of soybean production in different provinces and regions. The comparative advantages of various provinces and regions in production of different soybean varieties vary from each other due to the different resource endowment, geographical location and market distribution. The goal we have always strived for is to develop the strong points and avoid the weak points, thus to maximize the efficiency of soybean production in China [18]. Based on the cross-section data of 31 provinces, autonomous regions and municipalities directly under the Central Government in 1978, 1980, 1990, 2000, 2010 and 2017, this article applies the comparative advantage index of the production of different soybean varieties in these provinces and regions and the decomposition index (efficiency advantage index and scale advantage index) and thus analyzes the spatial production advantage of different soybean varieties in different provinces and regions. The soybean production comparative advantage index is selected by referring to the “revealed comparative advantage index” (RCA) commonly used in international trade [19]. The calculation formula is as follows:
The soybean yield is the product of the planting area and the yield per unit area, i.e. \( Q = M \cdot N \). Hence we can further acquire the efficiency advantage index and scale advantage index of soybean production as follows [20]:

\[
CAI_{ij} = Q_{ij} / Q_i \times M_i / M
\]

\[
= (N_{ij} / N_i \times M_i / M) \cdot (M_{ij} / M_{ij} \times M_i / M)
\]

\[
EAI_{ij} = N_{ij} / N_i \times M_i / M
\]

\[
SAI_{ij} = M_{ij} / M_i \times M_i / M
\]

Where \( CAI_{ij} \), \( EAI_{ij} \) and \( SAI_{ij} \) respectively represent the comparative advantage index, efficiency advantage index and scale advantage index of the crop j in the province i. \( Q_{ij} \), \( N_{ij} \) and \( M_{ij} \) indicate the yield, yield per unit area and planting area of crop j in the province i, respectively. \( Q_i \), \( N_i \) and \( M_i \) respectively denote the total yield, per unit yield and planting area of all soybean in the province i, and \( Q \), \( M \) and \( N \) respectively represent the total yield, per unit yield and planting area of grain in China. The soybean production advantage index \( CAI_{ij} \) reflects the comparative advantage of soybean production in a province through the relative value of soybean production in the province to that in whole China. If \( CAI_{ij} > 1 \), the province has comparative advantage in producing soybean, and the higher value suggests the more evident advantage; and if \( 0 < CAI_{ij} < 1 \), the province shows no comparative advantage in soybean production, and the closer the value gets to 0, the comparative advantage is less evident and the comparative disadvantage is more prominent.

The comparative advantage index of soybean production in a province \( CAI_{ij} \) is the product of the efficiency advantage index \( EAI_{ij} \) and the scale advantage index \( SAI_{ij} \) of soybean in this province. Here, the efficiency advantage index \( EAI_{ij} \) measures the soybean production efficiency in province i relative to that in whole China through the relative value of the per unit yield of soybean in province i to the per unit yield of soybean in China. The scale advantage index \( SAI_{ij} \) measures the soybean production scale in province i relative to that in whole China through the relative value of the planting area of soybean in province i to the planting area of soybean in China. The efficiency of soybean production in different provinces and regions not only depends on the resource endowment, scientific and technological level and capital investment of the region, but is also influenced by the local organization mode of soybean production and personnel quality [21]. Meanwhile, the scale advantage of soybean production in different provinces and regions relies mainly on the structural arrangement of soybean production in these regions, which is mainly adjusted according to the land resources, climatic conditions, market situation and policy changes there [22]; and in case of no major change of the above factors, the scale advantage of soybean production in various provinces and regions shows smooth changes. Through the calculation, we can acquire the comparative advantage index, efficiency advantage index and scale advantage index of soybean production in 31 provinces, autonomous regions and municipalities directly under the Central Government in 2017.

3. Results

3.1. Evolution of soybean producing areas’ comparative advantage in production

Through the calculation, we can figure out the soybean producing areas with the most comparative advantage and those with the least comparative advantage in China between 1978 and 2017. Here we choose to examine the changes of the soybean producing areas with the most comparative advantage in 6 typical years, 1978, 1980, 1990, 2000, 2010 and 2017 (see Table 1). According to the result, Heilongjiang Province has always been the first place among the soybean producing areas with the most comparative advantage in the four decades; and always being the center of soybean production in China [17], Heilongjiang plays an essential role in China’s soy production. In the meantime, Inner
Mongolia Autonomous Region (hereinafter referred to as Inner Mongolia) has replaced Jilin Province as the second place among the soybean producing areas with the most comparative advantage in China. Before 1980, Inner Mongolia showed no characteristic of an advantageous soybean producing area, but had risen to the second place in China’s soybean production after 1990. Even in the year of 2000, Inner Mongolia ranked No. 3 in all provinces in terms of soybean production. All these demonstrate that Inner Mongolia has become a strong soybean-producing province in name and in fact. The third place of the producing areas with the most comparative advantage has changed from the “three-province region” including Liaoning, Jilin and Inner Mongolia to the Huang-Huai-Hai area. Remarkably, Zhejiang became the third place of the producing areas with the most comparative advantage. The regions of the fourth to the sixth place in this list are mainly distributed in other Huang-Huai-Hai areas such as Henan, Shandong and Anhui, and also include multiple-crop areas in the south such as Yunnan.

Soybean is now planted in all places in China except Qinghai. Seen from the calculation results (see Table 1), unlike the advantageous producing areas that are distributed in a relatively concentrated manner, the producing areas with the least comparative advantage are relatively dispersed. Meanwhile, the ranks of the producing areas with the least comparative advantage have been constantly changing, except that Ningxia has been the first place among the soybean producing areas with the least comparative advantage in the recent decade and Guangdong had ranked No. 5 in the list for 20 consecutive years from 1980 to 2000. Other ranks of the list have always been changing. Irrespective of the rank, the regions which often fall into the category of the producing areas with the least comparative advantage mainly include Shanghai (5 times), Guangdong Province (4 times), Hainan Province (4 times), Hunan Province (3 times), Sichuan Province (3 times) and Xinjiang Autonomous Region (3 times). Geographically, the producing areas with the least comparative advantage are mainly distributed in the south and southwest of China. In addition, Tianjin and Shandong had been the No. 5 and No. 4 of the soybean producing areas with the most comparative advantage before the 1990s, but had dropped to the No. 3 and No. 5 and 6 of the soybean producing areas with the least advantage in China by 2010. Apparently, besides the traditional disadvantageous soybean producing areas, some producing areas originally with comparative advantage have fallen to the disadvantageous places after 2000.

### Table 1. The soybean producing areas with the most and the least comparative advantage in China between 1978 and 2017.

| No. | Producing Areas with the Most Comparative Advantage | Producing Areas with the Least Comparative Advantage |
|-----|-----------------------------------------------------|-----------------------------------------------------|
|     | 1978 | 1980 | 1990 | 2000 | 2010 | 2017 | 1978 | 1980 | 1990 | 2000 | 2010 | 2017 |
| 1   | HLJ  | HLJ  | HLJ  | HLJ  | HLJ  | HLJ  | GD   | SH   | HN   | XZ   | NX   | NX   |
| 2   | JL   | JL   | IM   | JL   | IM   | IM   | XJ   | XJ   | SH   | YN   | HN   | SH   |
| 3   | LN   | LN   | JL   | IM   | SX   | ZJ   | SH   | SC   | XJ   | CQ   | XZ   | TJ   |
| 4   | HN   | HN   | TJ   | LN   | AH   | SC   | HN   | HN   | ZJ   | HN   | HB   | HN   |
| 5   | SD   | SD   | SX   | SX   | JL   | YN   | FJ   | GD   | GD   | GD   | GD   | HN   |
| 6   | SX   | AH   | LN   | AH   | YN   | AH   | SC   | HB   | SC   | SH   | SD   | SD   |

HLJ is abbreviation of Heilongjiang province in China. IM is of Inner Mongolia in China. The same below.

### 3.2. Evolution of soybean producing areas’ comparative advantage in scale and efficiency

Table 2 shows the comparison of scale advantage and efficiency advantage in terms of soybean production in various provinces, municipalities and autonomous regions in China at the beginning of the Reform and Opening Up (1978). Among the 6 producing areas with comparative advantage in soybean production, 5 areas saw the scale advantage index higher than the efficiency advantage index, with a ratio between the two indices ranging between 1.1 and 2.8. Shaanxi Province was a soybean producing area with the most comparative advantage, but its scale advantage index (0.77) was slightly
lower than its efficiency advantage index (1.30). In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index, and ranged between 0.05 and 0.41. The efficiency advantage index in all these producing areas with the least comparative advantage except Xinjiang and Sichuan was lower than 1, suggesting no efficiency advantage at all. To sum up, at the beginning of the Reform and Opening Up, the soybean producing areas with comparative advantage in China mainly relied on scale advantage (i.e. promoting the soybean yield by increasing the planting area) instead of efficiency advantage; and the soybean producing areas with no comparative advantage showed no scale advantage or efficiency advantage (except Xinjiang and Sichuan had a little efficiency advantage).

**Table 2.** Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 1978.

| No. | Region     | Producing Area with the Most Comparative Advantage in 1978 | Producing Area with the Least Comparative Advantage in 1978 |
|-----|------------|------------------------------------------------------------|-------------------------------------------------------------|
| 1   | Heilongjiang | Scale advantage index (3.46) > Efficiency advantage index (1.64) | Guangdong Scale advantage index (0.38) < Efficiency advantage index (0.52) |
| 2   | Jilin       | Scale advantage index (2.38) > Efficiency advantage index (1.10) | Xinjiang Scale advantage index (0.10) < Efficiency advantage index (2.24) |
| 3   | Liaoning    | Scale advantage index (2.34) > Efficiency advantage index (0.83) | Shanghai Scale advantage index (0.05) < Efficiency advantage index (0.68) |
| 4   | Henan       | Scale advantage index (1.60) > Efficiency advantage index (0.91) | Hunan Scale advantage index (0.35) < Efficiency advantage index (0.77) |
| 5   | Shandong    | Scale advantage index (1.07) > Efficiency advantage index (0.96) | Fujian Scale advantage index (0.41) < Efficiency advantage index (0.68) |
| 6   | Shaanxi     | Scale advantage index (0.77) < Efficiency advantage index (1.30) | Sichuan Scale advantage index (0.33) < Efficiency advantage index (1.09) |

Table 3 shows the comparison of scale advantage and efficiency advantage in terms of soybean production in various provinces, municipalities and autonomous regions in China in the 1980s. Among all the 6 producing areas with comparative advantage of soybean production, “the scale advantage index was higher than the efficiency advantage index”, and the ratio between the two indices ranged between 1.2 and 9.1. Liaoning Province, ranking the third among the soybean producing areas with the most comparative advantage, presented a scale advantage index (2.37) evidently higher than the efficiency advantage index (0.26), where the soybean production mainly relied on the scale advantage and showed no efficiency advantage. In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index, and ranged between 0.05 and 0.52; and only Xinjiang among the six saw an efficiency advantage index higher than 1 (1.89), suggesting that other producing areas with no comparative advantage had no efficiency advantage at all. In summary, the soybean producing areas with comparative advantage mainly depended on their scale advantage instead of efficiency advantage in 1980; and the soybean producing areas with no comparative advantage presented no scale advantage or efficiency advantage except that Xinjiang had a little efficiency advantage. Specially, Sichuan Province had risen from the 6th place to the 3rd place among the disadvantageous producing areas, where the efficiency advantage index dropped below 1, suggesting no efficiency advantage any longer, and the scale advantage index also declined.
Table 3. Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 1980.

| No. | Region       | Producing Area with the Most Comparative Advantage in 1980 | Region       | Producing Area with the Least Comparative Advantage in 1980 |
|-----|--------------|-----------------------------------------------------------|--------------|-----------------------------------------------------------|
| 1   | Heilongjiang | Scale advantage index (3.60) > Efficiency advantage index (1.68) | Shanghai     | Scale advantage index (0.05) < Efficiency advantage index (0.68) |
| 2   | Jilin        | Scale advantage index (2.55) > Efficiency advantage index (1.11) | Xinjiang     | Scale advantage index (0.11) < Efficiency advantage index (1.89) |
| 3   | Liaoning     | Scale advantage index (2.37) > Efficiency advantage index (0.26) | Sichuan      | Scale advantage index (0.12) < Efficiency advantage index (0.92) |
| 4   | Henan        | Scale advantage index (1.68) > Efficiency advantage index (1.03) | Hunan        | Scale advantage index (0.39) < Efficiency advantage index (0.66) |
| 5   | Shandong     | Scale advantage index (1.33) > Efficiency advantage index (1.07) | Guangdong    | Scale advantage index (0.42) < Efficiency advantage index (0.60) |
| 6   | Anhui        | Scale advantage index (1.64) > Efficiency advantage index (0.84) | Hubei        | Scale advantage index (0.52) < Efficiency advantage index (0.57) |

Table 4. Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 1990.

| No. | Region       | Producing Area with the Most Comparative Advantage in 1990 | Region       | Producing Area with the Least Comparative Advantage in 1990 |
|-----|--------------|-----------------------------------------------------------|--------------|-----------------------------------------------------------|
| 1   | Heilongjiang | Scale advantage index (4.19) > Efficiency advantage index (1.36) | Hainan       | Scale advantage index (0.18) < Efficiency advantage index (0.79) |
| 2   | Inner Mongolia | Scale advantage index (1.16) < Efficiency advantage index (1.70) | Shanghai     | Scale advantage index (0.19) < Efficiency advantage index (1.06) |
| 3   | Jilin        | Scale advantage index (1.97) > Efficiency advantage index (0.94) | Xinjiang     | Scale advantage index (0.11) < Efficiency advantage index (1.88) |
| 4   | Tianjin      | Scale advantage index (1.47) > Efficiency advantage index (0.96) | Zhejiang     | Scale advantage index (0.30) < Efficiency advantage index (0.95) |
| 5   | Shanxi       | Scale advantage index (1.15) > Efficiency advantage index (1.10) | Guangdong    | Scale advantage index (0.43) < Efficiency advantage index (0.69) |
| 6   | Liaoning     | Scale advantage index (1.67) > Efficiency advantage index (0.69) | Sichuan      | Scale advantage index (0.29) < Efficiency advantage index (1.12) |

Table 4 shows the comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in the 1990s. In 5 among the 6 soybean producing areas with comparative advantage, the scale advantage index was higher than the efficiency advantage index, with a ratio ranging between 1.0 and 3.1. However, in Inner Mongolia, ranking the 2nd place in the soybean producing areas with the most comparative advantage, the scale advantage index (1.16) was slightly lower than the efficiency advantage index (1.70). In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index and ranged between 0.11 and 0.43. Though lower than 0.5, the
scale advantage index in these 6 producing areas had grown compared to the past. The efficiency advantage index was lower than 1 except in Xinjiang, Shanghai and Sichuan, indicating no efficiency advantage at all. To sum up, the soybean producing areas with comparative advantage mainly depended on their scale advantage instead of efficiency advantage in 1990. The scale advantage was intensified and the efficiency advantage was lowered in Heilongjiang Province. Other soybean producing areas with the most comparative advantage had seen a decline of the scale advantage, while the soybean producing areas with no comparative advantage mainly relied on the little efficiency advantage. Hainan, Zhejiang and Guangdong had neither scale advantage nor efficiency advantage.

Table 5 shows the comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in the early 21st century. Among the 5 soybean producing areas with comparative advantage, the scale advantage index was higher than the efficiency advantage index in 5 areas, with a ratio between the two indices ranging from 1.2 to 3.4. In Shanxi Province which ranked No. 5 of the soybean producing areas with comparative advantage, the scale advantage index (0.99), suggesting no scale advantage, was lower than the efficiency advantage index (1.27). In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index and ranged between 0.03 and 0.34. While the efficiency advantage indices in Chongqing and Guangdong were lower than 1, indicating no efficiency advantage, the efficiency advantage index had significantly increased in the other 4 regions. In conclusion, the soybean producing areas with comparative advantage were mainly distributed in Heilongjiang and Inner Mongolia in 2000, and the comparative advantage index had been constantly rising. The soybean producing areas with the most comparative advantage still mainly depended on scale advantage but not efficiency advantage. In the meantime, the soybean producing areas with no comparative advantage mainly relied on the relatively low efficiency advantage. Chongqing and Guangdong showed no scale advantage or efficiency advantage.

Table 5. Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 2000.

| No. | Region       | Producing Area with the Most Comparative Advantage in 2000 | Region | Producing Area with the Least Comparative Advantage in 2000 |
|-----|--------------|-----------------------------------------------------------|--------|-------------------------------------------------------------|
| 1   | Heilongjiang | Scale advantage index (4.24) > Efficiency advantage index (1.25) | Xizang | Scale advantage index (0.03) < Efficiency advantage index (2.92) |
| 2   | Jilin        | Scale advantage index (1.63) > Efficiency advantage index (1.34) | Yunnan | Scale advantage index (0.14) < Efficiency advantage index (1.10) |
| 3   | Inner Mongolia | Scale advantage index (2.08) > Efficiency advantage index (0.99) | Chongqing | Scale advantage index (0.34) < Efficiency advantage index (0.71) |
| 4   | Liaoning     | Scale advantage index (1.23) > Efficiency advantage index (1.03) | Hainan | Scale advantage index (0.20) < Efficiency advantage index (1.21) |
| 5   | Shanxi       | Scale advantage index (0.99) < Efficiency advantage index (1.27) | Guangdong | Scale advantage index (0.34) < Efficiency advantage index (0.93) |
| 6   | Anhui        | Scale advantage index (1.28) > Efficiency advantage index (0.86) | Shanghai | Scale advantage index (0.28) < Efficiency advantage index (1.17) |

Table 6 shows the comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 2010. Among the 6 soybean producing areas with comparative advantage, 4 areas saw the scale advantage index higher than the efficiency advantage index, with a ratio between the two ranging from 1.0 to 4.0. Shaanxi Province and Yunnan Province, respectively ranking the 3rd and the 6th place in the producing areas with comparative advantage, showed no scale advantage and had their scale advantage indices (0.79 and
0.44) lower than their efficiency advantage indices (1.66 and 2.21). In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index, and was between 0.07 and 0.27, suggesting no scale advantage. In the meantime, all these areas except Ningxia had their efficiency advantage indices higher than 1. Ningxia had neither the scale advantage nor the efficiency advantage. In summary, the soybean producing areas with comparative advantage in China mainly relied on scale advantage in 2000, but efficiency advantage started to play a greater role. The soybean producing areas with no comparative advantage mainly depended on the low efficiency advantage which had significantly risen.

### Table 6. Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China in 2010.

| No. | Region         | Producing Area with the Most Comparative Advantage in 2010 | Region         | Producing Area with the Least Comparative Advantage in 2010 |
|-----|----------------|-------------------------------------------------------------|----------------|-------------------------------------------------------------|
| 1   | Heilongjiang   | Scale advantage index (4.09) > Efficiency advantage index (1.03) | Ningxia       | Scale advantage index (0.19) < Efficiency advantage index (0.22) |
| 2   | Inner Mongolia| Scale advantage index (2.19) > Efficiency advantage index (1.15) | Hainan         | Scale advantage index (0.09) < Efficiency advantage index (1.72) |
| 3   | Shanxi         | Scale advantage index (0.79) < Efficiency advantage index (1.66) | Xizang         | Scale advantage index (0.07) < Efficiency advantage index (2.50) |
| 4   | Anhui          | Scale advantage index (1.59) > Efficiency advantage index (0.74) | Hebei          | Scale advantage index (0.26) < Efficiency advantage index (1.06) |
| 5   | Jilin          | Scale advantage index (1.04) > Efficiency advantage index (1.02) | Shandong       | Scale advantage index (0.27) < Efficiency advantage index (1.12) |
| 6   | Yunnan         | Scale advantage index (0.44) < Efficiency advantage index (2.21) | Hunan          | Scale advantage index (0.24) < Efficiency advantage index (1.27) |

### 3.3. Soybean producing areas’ comparative advantage in production at present

Considering the availability of provincial data of soybean production, we choose the soybean production data of all Chinese regions in 2017 to study the comparative advantage of soybean production in China at present. Based on the calculation results, we have drawn the figure of soybean producing areas with comparative advantage in all provinces, municipalities and autonomous regions in China at present (Figure 1) with Tableau. It can be seen that in 2017, the soybean producing areas with comparative advantage (\(CA_{ij} > 1\)) in China included 6 provinces, respectively Heilongjiang, Inner Mongolia, Zhejiang, Sichuan, Yunnan and Anhui which are arranged in a descending order of the comparative advantage, compared to 14 regions of comparative advantage in maize production. Among them, Heilongjiang, Inner Mongolia and Zhejiang were the soybean producing areas with the most comparative advantage. Meanwhile, there were 25 provinces that fell into the category of producing areas with no comparative advantage (\(0 < CA_{ij} < 1\)). The producing areas with the least comparative advantage mainly included Ningxia, Shanghai, Tianjin, Hebei and Hainan etc. in addition to Qinghai where no soybean was planted. In summary, the soybean producing areas with the most comparative advantage were more concentratedly distributed in Heilongjiang and Inner Mongolia, and the producing areas with the least comparative advantage mainly comprised Ningxia, Hainan and Shanghai etc.

### 3.4. Comparison of scale and efficiency advantage at present

Table 7 reflects the comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China at present (in 2017). In the 6
soybean producing areas with comparative advantage, the scale advantage index was higher than the efficiency advantage index in 3 areas, with a ratio between the two ranging from 1.5 to 3.5. Zhejiang Province, Sichuan Province and Yunnan Province showed a little or no scale advantage, but ranked No. 3, 4 and 5 in the soybean producing areas with comparative advantage based on the great efficiency advantage. The scale advantage index of soybean planting in Zhejiang Province (1.18) was slightly lower than its efficiency advantage index (1.29). In all the 6 soybean producing areas with the least comparative advantage, the scale advantage index was lower than the efficiency advantage index, and ranged between 0.11 and 0.20, which was higher than the scale advantage index of maize. The efficiency advantage indices in these regions except Ningxia and Shanghai were all higher than 1, while Ningxia and Shanghai had neither scale advantage nor efficiency advantage. To sum up, the soybean producing areas with comparative advantage in 2017 had both scale advantage and efficiency advantage. The scale advantage was greater than the efficiency advantage regarding the absolute value. The soybean producing areas with no comparative advantage were exposed to the constant improvement of efficiency advantage, except in Ningxia and Shanghai.

**Figure 1.** Soybean producing areas with comparative advantage in all provinces, municipalities and autonomous regions in China at present (2017).
4. Discussions
The evolution of soybean producing areas with the most and the least advantage in China as well as the evolution of their scale advantage and efficiency advantage since the Reform and Opening Up have been closely associated with the government’s support to the soybean production industry and the comparative benefits between maize and soybean planting [23]. In the long run, the scale advantage index in traditional advantageous soybean producing areas is already high, which reflects the limited room for the growth of scale advantage of soybean production in these areas. Therefore, to promote the scale advantage of soybean production in China, we shall further explore the soybean producing areas other than Heilongjiang and Inner Mongolia etc. [24], such as the Huang-Huai-Hai area and multiple-crop areas in the south. In either the soybean producing areas with the most advantage or those with the least advantage, there is plenty of room to improve the efficiency advantage of soybean production [25]. In the future, considering the limited cultivated land resources, it is essential to study how to turn more soybean producing areas with the least advantage to the areas with advantage relying on the favorable policies of agricultural supply-side reform and the soybean rejuvenation plan. With regard to the traditional soybean producing areas and the producing areas with the most advantage, we shall reform the soybean planting industry and explore more approaches to improve the efficiency advantage. In this way, in addition to giving full play to the traditional scale advantage, we can further promote the efficiency of soybean production and rejuvenate soybean production in China.

Table 7. Comparison of scale advantage and efficiency advantage of soybean production in various provinces, municipalities and autonomous regions in China at present (in 2017).

| No. | Region       | Producing Area with the Most Comparative Advantage in 2017              | Region       | Producing Area with the Least Comparative Advantage in 2017              |
|-----|--------------|------------------------------------------------------------------------|--------------|------------------------------------------------------------------------|
| 1   | Heilongjiang | Scale advantage index (3.77) > Efficiency advantage index (1.07)        | Ningxia     | Scale advantage index (0.16) < Efficiency advantage index (0.54)       |
| 2   | Inner Mongolia | Scale advantage index (2.09) > Efficiency advantage index (1.04)     | Shanghai    | Scale advantage index (0.12) < Efficiency advantage index (0.78)       |
| 3   | Zhejiang    | Scale advantage index (1.18) < Efficiency advantage index (1.29)        | Tianjin     | Scale advantage index (0.14) < Efficiency advantage index (1.15)       |
| 4   | Sichuan     | Scale advantage index (0.84) < Efficiency advantage index (1.27)        | Hebei       | Scale advantage index (0.15) < Efficiency advantage index (1.28)       |
| 5   | Yunnan      | Scale advantage index (0.59) < Efficiency advantage index (1.72)        | Hainan      | Scale advantage index (0.11) < Efficiency advantage index (1.99)       |
| 6   | Anhui       | Scale advantage index (1.21) > Efficiency advantage index (0.83)        | Shandong    | Scale advantage index (0.20) < Efficiency advantage index (1.28)       |

5. Conclusions
Soybean is planted in all provinces, municipalities and autonomous regions of China except Qinghai Province. Since the Reform and Opening Up, scale advantage has still been the determinant to the soybean production advantages of an area, but efficiency advantage is playing a greater role in the producing areas with the most comparative advantage and those with the least comparative advantage. There is still plenty of room to improve the efficiency advantage in all soybean producing areas in China. Since the Reform and Opening Up, Heilongjiang Province has always been the first place among the soybean producing areas with the most comparative advantage [26]; Inner Mongolia has replaced Jilin Province as the second place of the soybean producing areas with the most comparative advantage since the 1990s; the comparative advantage of Liaoning Province in soybean production has
gradually weakened since the 21st century, while some regions in Huang-Huai-Hai area have ascended to Top 6 of the soybean producing areas with the most comparative advantage in China; and remarkably, Zhejiang Province has become the 3rd place of the soybean producing areas with the most comparative advantage in 2017 by improving its efficiency advantage in soybean production. The traditional large soybean producers such as Jilin Province and Liaoning Province are not in the list now. It is noteworthy that Shandong Province has changed from a soybean producing area with comparative advantage at the beginning of the Reform and Opening up to a soybean producing area with the least comparative advantage in China in the 21st century, which is largely associated with the reform of the agricultural planting structure in Shandong Province and the planting income. Ningxia has been a soybean producing area with the least comparative advantage in the recent decade. Shanghai, Guangdong and Hainan have always been the traditional producing areas with the least comparative advantage.

According to the calculation results of the scale advantage and efficiency advantage of both advantageous and disadvantageous soybean producing areas in all provinces, municipalities and autonomous regions in China since 1978, the producing areas with the most comparative advantage generally depend on the scale advantage to develop soybean production, and soybean production has been even more concentrated in soybean producing areas of Heilongjiang and Inner Mongolia. The scale advantage index has risen evidently in Heilongjiang and Inner Mongolia, where the scale advantage indices have always ranked No. 1 and 2 among all producing areas with the most comparative advantage and have been way above the indices in other producing areas (the scale advantage index of Heilongjiang Province has been approximately 4 throughout). However, the efficiency advantage indices in these two regions have not increased correspondingly, and, instead, have declined. We shall also note that an increasing number of non-traditional soybean producing areas with the scale advantage index lower than the efficiency advantage index fall into the category of the producing areas with the most comparative advantage. Among the current 6 producing areas with the most comparative advantage, 3 (Heilongjiang, Inner Mongolia and Anhui) develop soybean production relying on the scale advantage, and the other 3 (Zhejiang, Sichuan and Yunnan) show greater efficiency advantage than scale advantage and also see the constant improvement of efficiency advantage. The latter three regions were originally disadvantageous producing areas in the past, which demonstrates that the comparative advantage of efficiency has been intensified in disadvantageous soybean producing area. These disadvantageous producing areas have gradually bettered the suitability of soybean production through breeding of fine varieties and high-quality cultivation, and they can become advantageous soybean producing areas of China depending on their efficiency advantage. In the meantime, the soybean producing areas with scale advantage can also further improve their efficiency of soybean planting [27].

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