sustainability

MDPI

Review

Mechanization of Small-Scale Agriculture in China: Lessons for Enhancing Smallholder Access to Agricultural Machinery

Wangda Liao [1], Fusheng Zeng [1] and Meseret Chanieabate [2,*]

[1] School of Economics, Hunan Agricultural University, Changsha 410128, China; liaowangda@126.com (W.L.); zefusheng@163.com (F.Z.)
[2] Research Institute of Rural Revitalization, Hunan University of Science and Engineering, Yongzhou 425199, China
* Correspondence: abatemeseretchanie3407@huse.edu.cn; Tel.: +86-157-7315-8953

Abstract: Developing countries with small-scale agriculture have yet to exploit the untapped potential of agricultural mechanization. This is because of the misconception that mechanization is often seen as unworthy in small-scale agriculture. The purpose of this paper is to examine the development of agricultural mechanization in China and to provide evidence on how smallholder farmers can access agricultural machinery. A narrative approach was employed to conduct an in-depth analysis of the policies, strategies, and trends associated with agricultural mechanization development. The findings showed that: (1) the establishment and development of mechanization for smallholder agriculture is an evolutionary process that strongly opposes leapfrogging (technocratic behavior) and making large jumps; (2) the foundation of mechanization development should rely on a self-reliance system; (3) an appropriate mechanization theory is the key to inducing the rapid growth of mechanization in small-scale agriculture; (4) the successful application of agricultural machinery requires strong, target-oriented, and pro-farmer policies with effective leadership strategies. We present the key lessons on policy and institutional aspects for countries with small-scale agriculture and who are in the initial stages of agricultural mechanization.

Keywords: agricultural mechanization; small-scale agriculture; smallholder farmers

check for updates

Citation: Liao, W.; Zeng, F.; Chanieabate, M. Mechanization of Small-Scale Agriculture in China: Lessons for Enhancing Smallholder Access to Agricultural Machinery. *Sustainability* **2022**, *14*, 7964. https://doi.org/10.3390/su14137964

Academic Editors: Aurora Cavallo, Francesco Maria Olivieri and Benedetta Di Donato

Received: 11 May 2022
Accepted: 6 June 2022
Published: 29 June 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Agricultural mechanization is an important component in the agrarian economic transition, and plays a key role in improving agricultural labor productivity, thereby contributing to sustainable food security and alleviating rural poverty. Agricultural mechanization is more advanced in countries with large-scale agriculture. This paradigm forces small-scale agricultural countries to scale up their agriculture rather than apply scale-appropriate mechanization with the utilization of small-scale agricultural machinery on small-scale farmland [1]. Conversely, the scaling-up of agriculture should be undertaken simultaneously with farmland-scale management and agricultural service-scale management, which needs longer-term efforts to be made in farmland policies and a huge commitment of resources [2].

Recently, there has been renewed interest in investigating the untapped potential of agricultural mechanization, particularly in developing countries with small-scale agriculture. In the attempt to revitalize rural areas, the significant role of agricultural mechanization has emerged as a tool to harmonize the rural–urban labor structure [3–5]; as a mechanism to create a division of labor and specialization in the agriculture sector [6]; as a symbol of modern agriculture [7]; a measure to reduce the rural–urban income gap; a means to expand agricultural-scale operations [8–11]; as a solution to mitigate climate change-associated problems (agricultural mechanization, when carefully applied and appropriate to the agricultural practice, is capable of protecting natural capital and the environment

whilst boosting food production) [12]; and as a decisive factor for commercializing agriculture and enhancing agricultural competitiveness [13]. However, countries with small-scale agriculture have yet to exploit the untapped potential of mechanization mainly because of a misinterpretation that only large-scale mechanization offers these multidimensional benefits. To cope with this challenge, scale-appropriate mechanization has gained attention in some African and Asian countries. For instance, in Nepal, the adoption of a small-scale mechanization strategy not only enabled smallholder farmers to access cost-effective machines but also assisted them in utilizing machines in hilly farmlands and in improving the productivity of the smallholder farmers [14]. Similarly, in China, since the nature of agriculture is small-scale, small tractors have been dominantly utilized by smallholder farmers [15].

China has achieved large agricultural productivity improvements [16] in terms of its production, conditions and incomes. The two most critical measures for the rapid growth of agricultural productivity are, first, that the government makes critical adjustments to the agricultural supply-side structure through land and labor policies [17] and second, that the gap created by a huge rural to urban center exodus is filled. To this end, the country has enhanced a rapid uptake of agricultural machinery to substitute for the migration of young and skilled agricultural laborers [18]. The government of China leads a development paradigm where everyone from the minister down to the counties and district-level governments is fully involved in the effort to mechanize small-scale agricultural production. Consequently, mechanization in China can be featured as a self-reliance enhancement, where the domestic agricultural machinery industries play a pivotal role in supplying the farm machines demanded by farmers [19]; are shaped by laws, since the government promulgates agricultural mechanization laws to allocate the right machines to the right farmers at the right time [20,21]; and are incentive-oriented, using strategies such as subsidies to farmers, agricultural cooperative organizations, and agricultural operators for purchasing agricultural machinery. Moreover, in the country, mechanization is always regarded as a symbol of modern agriculture and the application of agricultural machinery is an increasing trend; however, some challenges do still exist. For instance, the comprehensive mechanization level of crops was only 68% in 2020, implying that the country's mechanization process has space yet to grow [22]. The level of mechanization is also uneven among regions (being higher in south-eastern China than in western China), in crop-types (being higher in rice than in wheat and corn), and in agricultural practices (where agricultural machinery application in tillage is much higher than in harvesting and processing) [23].

This paper aims to: (1) examine the evolution and development of agricultural mechanization; (2) elucidate the trends of agricultural mechanization level growth; (3) reveal the role of mechanizing small-scale agriculture; (4) present the driving force for smallholder farmers' access to agricultural machines; (5) unveil agricultural machinery hiring service provision models. We conducted an in-depth analysis of mechanization development and describe for the policymakers in developing countries how China has reached its current level of mechanization. China's mechanization is not complete and, thus, this paper contributes a fundamental analysis of China's efforts to reach complete mechanization. As China's agriculture closely resembles the agriculture of many developing countries, this study puts forward China's experiences, challenges, successes, and mechanisms as a model for mechanizing small-scale agriculture from scratch in other countries with an infant agricultural mechanization industry.

Conceptual Framework of Land, Machine, and Labor Nexus

Researches on agricultural mechanization development rely mainly on investigating the labor–land–machine nexus [18,24]. It has been largely reported that a moderate land scale, sufficient supply of skilled labor, and accessibility of appropriate mechanization can induce the rapid growth of agricultural productivity. In developing countries, the failure to

establish any of these can exacerbate the integration of the whole and results in inefficient agriculture, rural poverty, and food insecurity.

Figure 1 presents the labor–machine–land nexus in China. The major rural reform and opening up that occurred in the late 1970s, resulted in a dual economic structure of the rural and urban economies, and industrialization remained the priority for national economic development. The reform dismantled the people's commune land system and replaced it with the household responsibility system (HRS). The HRS disseminated farmlands to farmers based on an egalitarian principle, resulting in millions of smallholder farmers with small and fragmented plots (cultivated area per household, 0.464 ha; number of plots per household, 5.8 plots; and average size of each plot, 0.08 ha.). Meanwhile, the existence of surplus agricultural labor is responsible for the present, persistent problem [25].

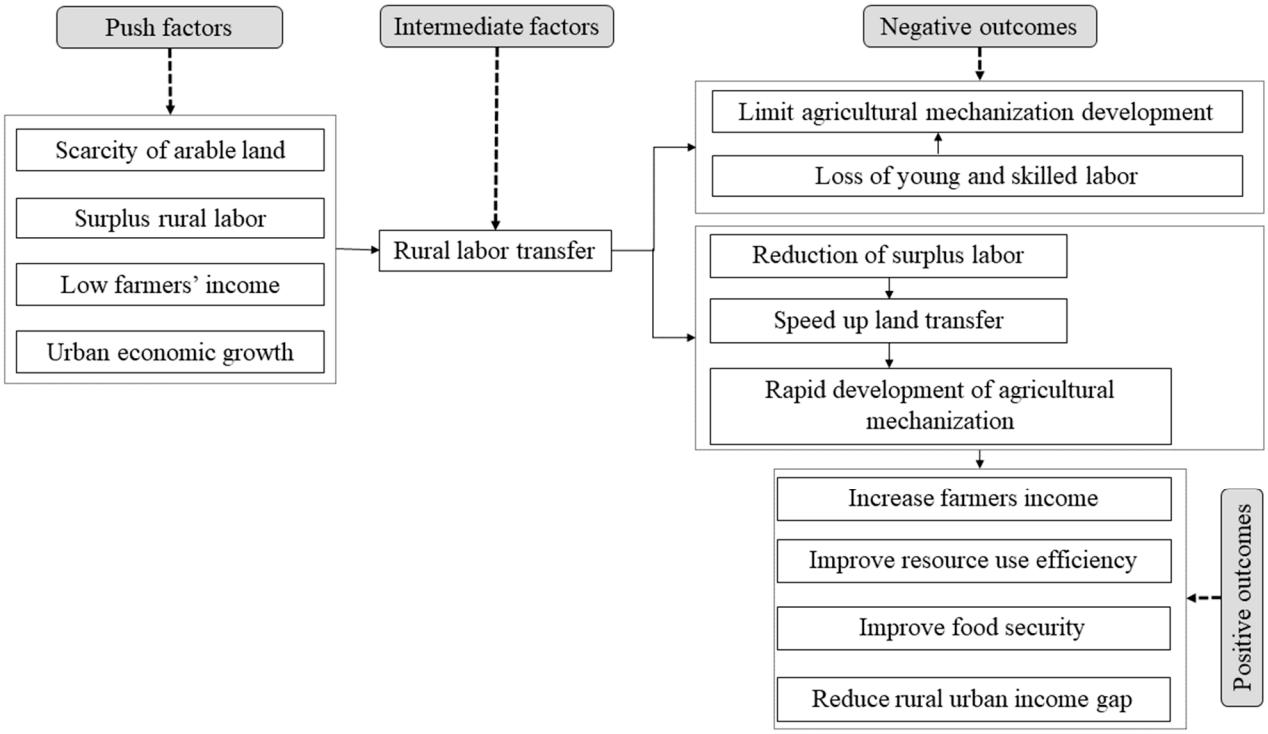


Figure 1. Conceptual framework of land, machine and labor nexus.

In the 1990s, the industrial sector in the urban and coastal areas showed a rapid growth, with real wages increasing and a significant amount of rural labor migrating to non-agricultural employment [18]. This transfer of labor created an opportunity to reduce the production costs of labor-extensive crops while increasing the production costs of labor-intensive crops. Additionally, the government slowly relaxed the restrictions on the household registration of migrant labor in urban areas.

When farmers left their farms, they tended to rent (land-rent out) their farms to other farmers (land-rent in), and an expansion in the scale of farmland became a common phenomenon in China's agriculture. Ref. [26] reported that rural households lacked farm-level labor and announced that China had reached the Lewis turning point. The transfer of agricultural labor created a space for the rapid introduction of agricultural machinery; however, smallholder farmers are unable to buy agricultural machines. Thus, the establishment of a mechanization rental service, mechanization laws, and a government subsidy since 2004, have since enabled farmers to access these machines at a rapid pace. The development of mechanization supports China's transition to moderate and large-scale farmland operations, releasing labor for secondary and tertiary industries.

2. Materials and Methods

This study uses a narrative approach to present the overview of the development process of agricultural mechanization in China and provides a sense of direction for policymaking and future studies for developing countries in the early stages of agricultural mechanization. A narrative in this study was regarded as a storyline about the past, present, and future-based scenarios and assumptions about the development process of agricultural mechanization. The narratives were retrieved from peer-reviewed scholarly articles and conference papers obtained from Web of Science, google scholars and Scopus. In addition, to understand the trends associated with the mechanization of small-scale agriculture, we used supporting documents organized by governmental and non-governmental institutions. The narratives provided the bases for deep analysis of the time series information of policy and strategies taken to enable smallholder farmers to access agricultural machines. A mix of content-based and expert view analysis approaches were taken that assumed a link between a narrative and an experience. We draw the conclusions based on the finding-based analysis of journal articles, other supporting documents, and experts' views. We chose five experts in the field of agriculture to discuss the issues related to the mechanisms of how smallholder farmers in China access agricultural machines.

2.1. Article Selection Criteria

Table 1 shows the selection criteria of the included articles. Articles published in the English language with a main focus on agricultural mechanization in China were considered. Conversely, those published in languages other than English were excluded. The paper considered articles published over the period between 2000–2021. The articles should have been published through peer-reviewed journals and articles that addressed the factors affecting mechanization development in China and other countries were considered. The data were extracted from the papers included in the review. The motivation was to present information on the development of agricultural mechanization in China. Moreover, we elucidated the mechanisms for how smallholder farmers could gain access to agricultural machinery.

Table 1. The inclusion and exclusion criteria.

Criterion	Eligibility	Exclusion
Literature type	Research article journal	Review article journal, book, book chapter, book series, conference proceedings
Language	English	Non-English
Time-line	Between 2000 and 2021	<1999
Countries and region	China	—

2.2. Search Result

A total of 328 studies were retrieved from the databases (Web of Science = 135, SCOPUS = 64 and Google Scholar = 129). A hand search provided 11 additional relevant articles on the topic under investigation, resulting in a total of 339 retrieved research articles. From the total searched articles, 104 were duplicates and 206 were excluded based on their titles and/or abstracts, as they did not fulfil the inclusion criteria. The final review included 29 articles. Moreover, 26 articles were added to critically observe the interactions among the factors that affect agricultural mechanizations. A few of these studies were studies from other countries but which provided substantial information on the mechanization of small-scale agriculture. Detail of the studies presented in the Supplementary Materials file.

3. The Evolution and Development of Agricultural Mechanization in China

Clearly observing the development process of agricultural mechanization is a critical component of research on agricultural production, rural development, rural-labor produc-

tivity, and food security. Investigating the evolution and development of mechanization relies on (1) examining the transformation of agricultural power sources from human power to animal power and then to machine power, in an effort to reduce the drudgery and improve both the quality and the quantity of food production through an agricultural power transfer; (2) an analysis of the positive and negative factors of mechanization development associated with farmers, rural areas, agriculture systems, and national and international policies; (3) evaluating the effectiveness of policy and strategic measures to mechanize agriculture production; (4) examining the challenges and trends in mechanization development; (5) elucidating the trends in mechanization levels.

Over the last six decades, China has considered mechanization a fundamental tool and strategic goal for building a modern socialist agriculture system [27] and the need for food security and increasing rural incomes have been the two most important factors driving the development of mechanization in the country. In this article, the evolution and development trend of China's mechanization are classified into five major phases since 1949, based on the changes in major socio-economic policies that have directly or indirectly affected that mechanization development, because rapid mechanization happened when the government made the appropriate political and economic reforms [28]. Figure 2 presents the five major phases of mechanization development in China associated with the major economic policy events.

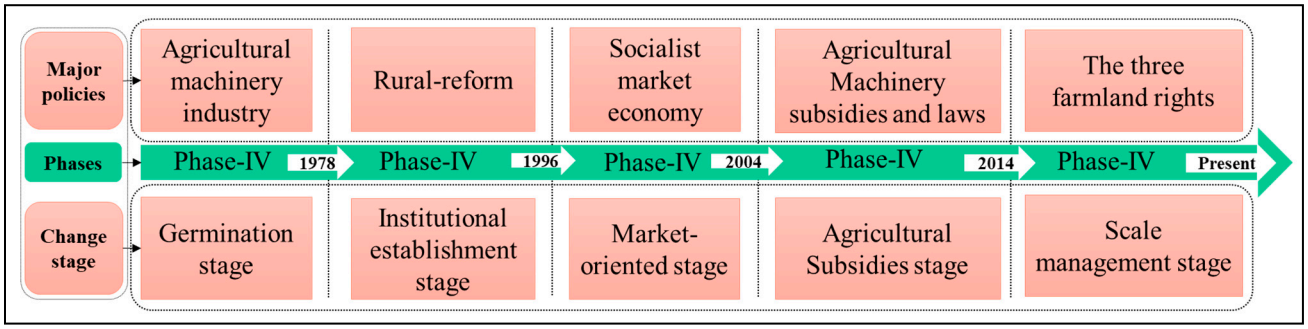


Figure 2. The evolution and development of agricultural mechanization in China.

3.1. Phase-I: Agricultural Mechanization (Germination Stage): 1949–1978

In China, the initial foundation of mechanization was formed in 1949 with the establishment of the People's Republic of China [29]. In 1949, Chairman Mao replaced the feudal land ownership system with collectivization, a type of agricultural production system in which multiple farmers would be engaged in holdings as a joint enterprise [30]; however, the percentage of the rural population was 89.4%, while the urban population was 10.6% [31], meaning that the agricultural production system was unable to feed the population. In this phase, the state began to create institutions to substitute the traditional farming tools with machines [29].

China established the first agricultural machinery manufacturing factories and towing machines during the first five-year plan (1953–1957). In this phase, a complete set of agricultural machinery support service systems from the central to the local level were established, and peasants were mobilized to actively participate in the application of agricultural machinery; however, the centrally-planned economic system managed the state-owned mechanized farms and tractor stations in a centrally-planned way. This created a contradiction between the state-owned tractor stations in production organization, operation management, and the collective peasant economy.

In the 1950s, China was a close ally of the Soviet Union and fully accepted and practiced the Soviet economic model, even though it did not fit with China's situation. The major features of the Soviet economic model included the state ownership of capital goods, such as raw materials, facilities, machinery, and tools used in the production of goods and services, collective farms, and state-owned industrial manufacturing [32]. In 1958, the state

decided to destroy the centralized operating system of the state-owned tractor stations and adopted a decentralized system to distribute the tasks and responsibilities to people's communes. In 1960, almost all the tractor stations were changed into people's commune tractor stations; however, due to a weak economic foundation and a lack of skills, many people's communes failed to reach large-scale production levels. In 1966, the state proposed a target to achieve fundamental mechanization by 1980, and a relatively rapid development of mechanization was observed.

3.2. Phase-II: Agricultural Mechanization (Institutional Establishment Stage): 1978–1995

China conducted deep rural reforms from the late 1970s. Researchers reveal that the two important driving forces for China in conducting this deep rural reform were food insecurity and rural poverty [33]. Firstly, the production, testing, distribution, and after-sales service of agricultural machinery became institutionalized. This greatly helped the development of agricultural machinery by creating specialization and a division of labor among institutions. Secondly, the overall economic reform changed the structure of the agriculture-dominated economy to an industrial-based one. As a result, many domestic agricultural machinery industries were established. Thirdly, the agricultural machinery industry was liberalized and farmers began to use agricultural machinery independently. Meanwhile, social and non-governmental organizations entered the agricultural machinery industry and this relaxed the market system for agricultural machinery.

The most important features of this period were the state's relaxation of regulations that allowed farmers to independently purchase and operate agricultural machinery [27]. The state reduced and, at times, exempted the tax and set-up subsidies for agricultural machinery enterprises to sustain their production. The state arranged for the supply of millions of gallons of cheap diesel oil for rural areas every year to reduce the cost to farmers and encourage the use of agricultural machinery. Moreover, the state continued to administer the financial system under a planned economy to supply agricultural machinery to rural areas at a lower price. The state also allowed agricultural machinery to enter the market as a commodity and, thus, the role of the market in the development of mechanization gradually increased.

In 1983, the government empowered individuals, collectives, individual farmers, joint operations, and cooperative operations. This increased the income of agricultural machinery operators and the vitality of mechanization for the rural economy as the state-command management of agricultural machinery weakened. The separation of agricultural machinery management and its use over this period caused economic inefficiency in the mechanization process. To tackle the problems of machinery quality, the state established agricultural machinery safety supervision agencies at the county level. In this stage, the government thereby acted to fundamentally change the institutional structure of mechanization.

3.3. Phase-III: Agricultural Mechanization (Market-Oriented Stage): 1996–2003

In this phase, the economic system became market-oriented [34], thereby expanding the market processes of mechanization. Since the 1990s, the rapid expansion of industrialization and urbanization has caused two major effects. Firstly, the establishment of various rural off-farm enterprises induced the transfer of rural labor from farms to rural off-farm industries. Secondly, huge amounts of rural labor transferred to the industrialized urban and coastal areas for better employment opportunities. This led to a shortage in the rural labor force, especially during the peak harvesting season. Thus, the demand for agricultural machinery increased and the agricultural machinery market became a conducive environment for expansion. In this phase, the involvement of private enterprises in agricultural machinery increased.

3.4. Phase-IV: Agricultural Mechanization (Agricultural Subsidies Stage): 2004–2014

This phase was the golden age of mechanization development in China for two fundamental reasons. Firstly, in 2004, the government of China promulgated the national AM promotion law. The law was designed to inspect, monitor, and ensure the quality of agricultural machines. Secondly, in 2004, China officially introduced a direct agricultural machinery subsidy policy to farmers, agricultural operation organizations, and financial institutions to purchase advanced agricultural machinery [21,35]. Various mechanization subsidies were enacted to support the distribution, production, marketing, inspection, after-sales service, and end-user training for agricultural machines and the most rapid development of mechanization was recorded in this phase.

3.5. Phase-V: Agriculture Mechanization (Scale Management Stage): 2014-Present

In recent years, China has seen a great need for moving away from small-scale agriculture to moderate-scale operations [8]. Scale agricultural operations have three primary pillars: the agricultural machinery scale, farmland size scale, and service management scale. Finding a perfect agricultural machinery industrial system that can meet the demands of scale operations is a prerequisite for the scaling up of agricultural operations. In 2014, the government divided land rights into land ownership, contract, and management rights. This acceleration in the farmland transfer process established a farmland scale more able to accommodate large-scale machinery. In 2019, the comprehensive crop mechanization level reached 67%, after reaching 32% in 2002, almost doubling the level within two decades, and a target of 75% was set for 2025.

Mechanization of the agricultural operation system is a complex process and unevenness occurs in the crop production chain. The mechanization level at the production stage is far higher than at the pre- and post-agricultural production stages. Moreover, the mechanization level is uneven among different regions, being understandably higher in the more economically developed regions than in the less economically developed areas. At present, China is on the move to realize moderate-scale agricultural production levels [36]. Firstly, the government is encouraging farmland transfer to dismantle small land plots and land fragmentation to instead create moderate- and large-scale farmlands. Secondly, the agricultural management service system is establishing a large-scale system. Thirdly, the government is pushing the mechanization sector to take action to induce a rapid application of large-scale agricultural machines. China plans to establish a complete agricultural machinery industry by the year 2025 and this study is very optimistic about the achievement of this plan.

4. Trends and Status of the Agricultural Mechanization Level in China

Studies examining the status of mechanization are very limited. The status, meanwhile, is determined by two indicators: the level of mechanization and the level of agricultural equipment. Previous studies have agreed that, except for the agricultural equipment level, the other indicators have been used interchangeably. The mechanization level indicates the proportion of the farming activities, such as plowing, seeding, and harvesting, that are operated by farm machines [20]. The agricultural equipment level indicates the number of machines or power of machinery utilized in a region.

The mechanization level is simply the proportion of agricultural practices that are conducted mechanically. Previous studies have usually calculated the mechanization level of a given region based on indicators such as the mean tractor power, mean tractor power per area worked, mean area worked per tractor, mean number of tractors per 1000 ha, and the mean number of agricultural machines per 1000 ha [37]. Indicators to measure the agricultural equipment level include the total power of agricultural machinery or the total number of agricultural machines, such as tractors, threshers, combine harvesters and other mechanical equipment. Since the mechanization level measures the holding quantity and the technical level of mechanization that applies to crop production, researchers usually

apply this as a tool to measure the status of mechanization. The mechanization level, therefore, measures the degree of the use of machinery in agricultural operations.

China is attempting to fully mechanize the overall agricultural production chain and the mechanization level at the production stage has been far higher than at the pre- and post-production stages. In 1996, the government relaxed the market system and agricultural tractors were imported from other countries. The local manufacturing industry also paid more attention to producing tractors within the country. The integration of information technology with agricultural mechanization to modernize agriculture has, thus, become the priority issue for agricultural policy and strategies. Since 2016, advanced technology, such as automation and artificial intelligence, has been promoted in various research and academic institutions. As it can be seen in Figure 3, China's mechanization development follows the step-by-step principle, which has failed in the other developing countries with small-scale agriculture that have attempted it.

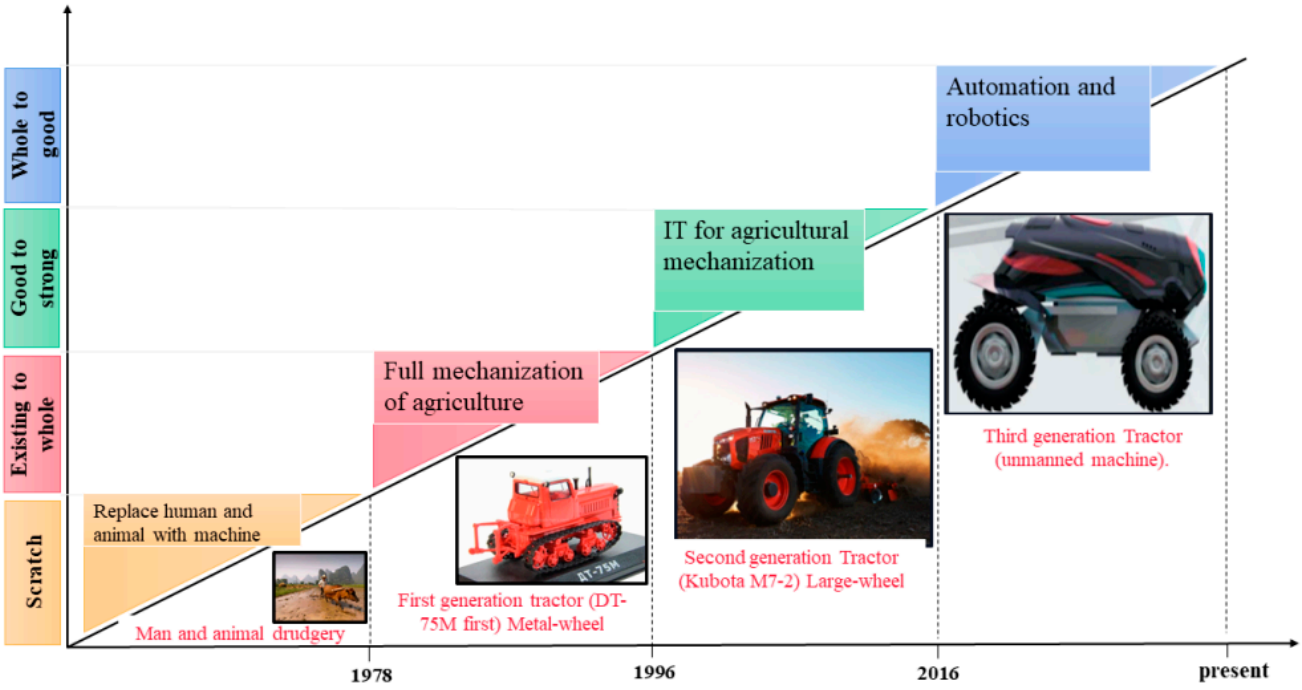
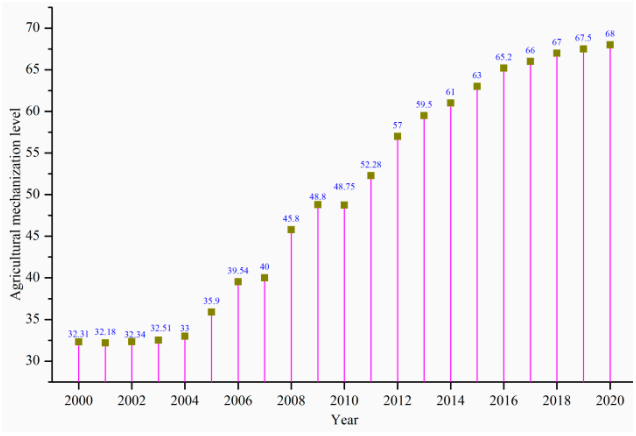


Figure 3. The past, present, and future characteristics of the agricultural mechanization level in China.

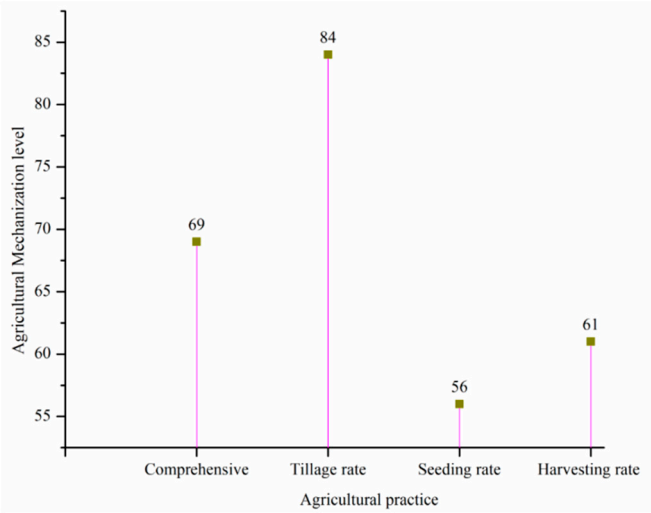
The development level of mechanization was examined through the comprehensive mechanization rate of crop cultivation and harvesting. In 2015, China started the inclusive mechanization promotion of agricultural production. This indicates that China's mechanization had reached a development stage that pushed forward the whole process of farming operations.

Figure 4a shows the growth and percentage change in the comprehensive mechanization level of crop cultivation in China over the period 2000–2020. The comprehensive mechanization level of crop cultivation and harvest in China increased from 32.31% in 2000 to 68% in 2020, doubling in two decades. In 1995, the government sped up the implementation of the household responsibility system and allowed agricultural machinery private enterprises to become involved in the agricultural machinery industry. Thus, the mechanization level increased dramatically from 2004 to 2013. The two critical driving forces in this rapid growth were the implementation of agricultural mechanization laws and the agricultural machinery purchase subsidy policy in 2004. Researchers call the period from 2004 to 2013 the "golden age" for agricultural mechanization development in China; however, since 2014, the rate of growth has been steadily declining. In 2020, it reached 68%

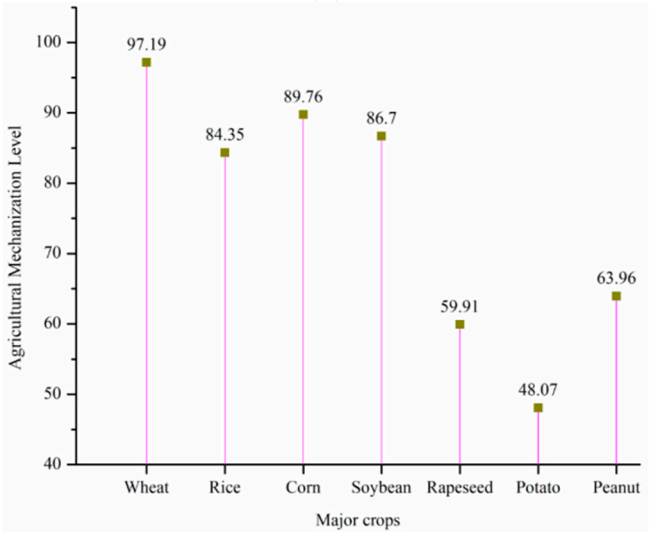
and China plans to realize a complete (100%) comprehensive mechanization level of crop cultivation by 2025.



(**a**)



(**b**)



(**c**)

Figure 4. The distribution of the agricultural mechanization level based on year (**a**), agricultural practices (**b**) and crop type (**c**) in China.

As indicated in Figure 4b, China's comprehensive mechanization rate in 2020 was 68%, and the mechanical tillage rate, mechanical seeding rate, and mechanical harvesting rate were 84%, 56%, and 61%, respectively. It can be seen that the mechanization level varied among the different agricultural practices. The tillage rate was 33.33% and 21.74% higher than the seeding rate and comprehensive rate, respectively. The mechanization rate at the seeding stage was the lowest as compared to the others. Moreover, as indicated in Figure 4c, the mechanization level also varied among the different major crops. For instance, the mechanization level of wheat was the highest, 15.22% and 21.05% higher than for rice and corn, respectively. At present, the level of agricultural mechanization in the United States, Japan, and South Korea has reached more than 99%; therefore, compared with developed countries, China's agricultural machinery growth level has room yet to grow.

5. The Role of Mechanizing Small-Scale Agriculture in China

The consistent growth of mechanization has laid a foundation for the rapid development of the national economy in China and mechanization is the engine to realize a modern agricultural system through improving the level of agricultural industrialization [7]. While the FAO and UNIDO claim that the main aim of mechanization is to reduce agricultural labor, it also has an invaluable role in revitalizing rural prosperity. Mechanization provides agricultural economic growth [9] and comprehensive rural prosperity [27]. Besides being a game changer to rapidly construct the rural economy, mechanization also promotes the adjustment of the agricultural and rural economic structures [38]. The following section discuss the potential value of mechanization in China.

5.1. Mechanization to Induce Agricultural Economies of Scale

Agricultural scale operations rely on a four-factor management scheme: (1) farmland scale management, in that small and fragmented farmland is consolidated to create large scale farms; (2) agricultural machinery scale management, where the scale of the agricultural machines should be matched to the scale of the farms; (3) agricultural service scale management, where agricultural service management, such as agricultural input service management, should be matched with the scale of an agricultural operation; (4) scale management of agricultural innovations where novel agricultural technologies, new agricultural business models, and new farming practices should be managed based on the scale of a farm's size [39]. The farms–machines–input services scale nexus is, therefore, a critical component for proper agricultural scale operations management which should be managed in an integrative and collaborative manner.

The scale of mechanization mainly depends on the scale of farmland; large machinery for large farms and small machinery for small farms. Optimizing the machine and land scale is one of the critical tasks in the effort to gain the best from mechanization; however, one of the most critical failures of mechanization in most developing countries is the mismatch between farmland size and machinery size, due to a misconception that agricultural machines are only profitable at a large scale. Being small-scale does not necessarily mean that agriculture must have small-scale production. Instead, the strong management capability of scale operations determines the productivity of agriculture. In China, smallholder farmers with small-scale farms and small-scale agricultural machinery support grain security. Moreover, the implementation of the household responsibility system during the previous major rural reform, resulted in a significant number of smallholder farmers. Since then, farmers have preferred using small tractors compared to large tractors based on the smaller scale of their land [27].

In recent years, due to the government's ambition to create moderate and large-scale agriculture, large agricultural machines have become increasingly prominent. It can be seen that the expansion of farmland size induced by farmland transfer among the transferred farmers to off-farm employment and the farmers who stayed on their farms. The emerging large and moderate-scale farms create opportunities for employing large machines; however, the low large-machine purchasing power of smallholder farmers, the

inefficiency of domestic manufacturers to produce the required large machines, and poor agricultural input service management, hinder the rapid application of the larger machines.

5.2. Mechanization to Create a Division of Labor and Specialization

In agricultural production, all the bulky farming operations (plowing, sowing, harvesting, and transport) are conducted by a single farmer seasonally. As a result, agricultural labor remains unproductive since the farmer's attention is spread across multiple tasks and, consequently, the agricultural sector remains economically backward compared to the manufacturing sector. Adam Smith stated that the subdivision of labor in agriculture remained impossible and that, unlike the manufacturing industry, improving the productivity of labor in the agriculture sector through a division of labor and specialization would be unsuccessful [40]. Land fragmentation and the existence of farmers owning these fragmented parcels of farmland exacerbates efforts to create a division of labor in the agricultural sector; however, the application of agricultural machines for use in each agricultural operation would result in a division of labor in the agricultural sector because agricultural machines are agricultural practice-specific (e.g., plowing machines, sowing machines and harvesting machines).

Surprisingly, in Asian countries such as China, a division of labor and specialization is emerging in smallholder farmers with farm sizes averaging about 0.5 ha. In China, agricultural mechanization industrializes the agriculture sectors by creating a division of labor [6]. The establishment of agricultural machinery renting services first initiated in 2004, offer smallholder farmers access to farm machinery at reasonable costs, and those agricultural machinery service providers are agricultural cooperatives, companies, and special agents who rent out plowing machines, sowing machines, and harvesting machines to smallholder farmers. The farmers who own and rent their machines are specialized in either plowing, sowing, or harvesting services. This improves the prospects of China's agriculture industry from the benefits of having modernized and specialized farmers in the future.

5.3. Mechanization to Harmonize Rural–Urban Economic Disparities

The existence of surplus rural labor causes the agriculture sector to have low profitability, to remain a subsistence economy, to have a low rate of economic growth, to contain a huge unproductive labor force, and to lag behind secondary and tertiary industries. The presence of surplus agricultural labor is one of the main causes of land fragmentation that prevents the practice of agricultural economies of scale, resulting in an unproductive agricultural system. To cope with this problem, the dual economy model states that unproductive agriculture can relinquish its hold on the economy by releasing its surplus labor to developed, urban-based industries.

In China, during the last five decades, agricultural labor has shown a sharp decline for four fundamental reasons: (1) there has been a rapid growth of rural off-farm industries attracting huge numbers of rural laborers to take part in non-agricultural employment opportunities; (2) the government of China has been liberalizing urban household registration restrictions on agricultural labor and allowing them to migrate into the urban and coastal areas, resulting in a mass flow of rural labor to the cities in the 1990s/2000s; (3) the one-child policy imposed in the 1970s caused a decline in rural labor; (4) the aging and retiring of farmers induces a decline in rural labor. The transferred labor is mostly represented by young, skilled, and educated workers, resulting in an agricultural labor shortage. As a result, the agriculture industry has become dominated by older farmers with low skill and education levels, which sabotages the efforts to enhance farmers' income and to enhance agricultural production [41]. In most developing economies, the transfer of young and energetic rural labor to rural off-farm and urban industries expands the economic rural–urban disparities.

Agricultural machinery plays a mediating role to induce a healthy labor allocation [24] in four ways: (1) agricultural machinery can be substituted for the labor source gap created

by the transfer of young and skilled labor; (2) agricultural machinery enhances agricultural labor productivity by reducing the pressure on farmlands created by the existence of surplus-labor, such as from farmland fragmentation. The development of mechanization allows a liberated labor force to engage in other important rural off-farm and urban-based industries; (3) the application of agricultural machinery frees up labor and provide workers for urban industries; (4) agricultural machinery indirectly creates an income source for the transferred rural labor force in urban industries to support their families who may remain in agriculture. Consequently, mechanization has a "kill two birds with one stone" type role, i.e., it provides a reliable guarantee for the transfer of a surplus rural labor force while offering this labor force as a source of labor to the secondary and tertiary industries. Mechanization is, therefore, a driver to efficiently allocate labor and to adjust the rural–urban dual economic structure.

5.4. Mechanization to Increase Farmers' Income

The mechanization of small-scale agriculture aims to boost the economy of smallholder farmers. Smallholder farmers in developing countries are at the lower end of the economic scale, often stricken by chronic poverty and their lower production efficiency results in lower incomes. The introduction of agricultural machines can provide a substantial increase in their income. Smallholder farmers gain income from mechanization through three channels. Firstly, the application of agricultural machines increases smallholder farmer incomes by reducing the cost of production, speeding up and qualifying the agricultural operation, and thereby enhancing yields. Secondly, smallholder farmers gain an income from renting their agricultural machines. The expansion of the mechanization rental service market in China allows potential farmers to become involved in this business and to earn extra income. Thirdly, the rapid application of agricultural machines frees up farmers to transfer to rural off-farm and urban-based industries for off-farm employment, generating an increase in non-agricultural wages. Thus, agricultural mechanization enables those farmers in off-farm employment to support their households in rural areas.

5.5. Mechanization as a Driving Force to Enhance Food Security

Due to increasing food availability, food accessibility, food safety, food utilization, and food preference, mechanization is the driving force behind enhancing food security [42]; thus, agricultural mechanization is the key to reducing malnutrition, famine, undernourishment, and starvation. Agricultural mechanization improves food security in three ways. Firstly, agricultural machinery induces the efficient use of agricultural inputs such as land, water, fertilizers, herbicides, and pesticides [43], by inducing precision and timeliness in the application of many of these agricultural inputs and resulting in a resource-use efficiency. This induces the optimum production of crops from the available resources. Additionally, the mechanization index increases crop variability [44], and by enhancing the timeliness of agricultural operations, mechanization can calculate the precise seasonality of crops, increase the utilization of land and increase the level of cultivation.

Secondly, mechanization increases labor productivity. Farm labor using traditional equipment and animal power is unable to perform bulky agricultural operations in a productive way within strict time constraints because the nature of agricultural practice requires a high-powered labor source. Food production chains such as tillage, seed drilling, seedling transplanting, weeding, fertilizing, agrochemical spraying, harvesting, threshing, and transport all need high power inputs. By efficiently performing these bulky operations, agricultural machinery improves labor productivity and boosts the crop yields to increase the productivity of labor per unit of time.

Thirdly, mechanization greatly enhances the quality of farm operations and reduces crop waste. Globally, about one-third of all food is wasted every year in different food production chains. The majority of food waste occurs when agricultural production is dominated by animal and human power [45]. By streamlining the agricultural production activities, agricultural machinery induces food security. Researchers have been debating

how China feeds 22% of the world's population with using only 7% of its farmland and how it has become the largest grain producer on the planet. The contribution of mechanization to this success is undeniable. China has formulated its strategy of mechanization development of an agricultural system that is dominated by small-scale agricultural cultivation and the primary objective of developing mechanization in China has been to speed up grain self-sufficiency, even though recently that mechanization has become a catalyst for comprehensive rural economic construction, thereby safeguarding all the previously discussed dimensions of food security.

6. Mechanisms to Improve the Capability of Smallholder Farmers' Access to Agricultural Machines

Improving the accessibility of agricultural machinery for smallholder farmers is the key task in improving farmers' productivity, thereby achieving food security and enhancing farmers' incomes. In developing regions, smallholder farmers cannot easily access farm machines due to their low purchasing power, poor knowledge, and poor market linkages. Moreover, there is a commonly accepted perspective that agricultural machinery is only suitable for large-scale farmland, preventing smallholder farmers from benefiting from mechanization. In this way, the likelihood of possessing agricultural machinery is connected with farmland size. China, however, has formulated and implemented various policies and strategies to improve smallholder farmers' access to agricultural machines. In this section, we discuss the five major factors which contribute to the improvement in the capability for agricultural machinery utilization of the smallholder farmers in China.

- Factor 1. Subsidizing farmers to purchase agricultural machinery (financial support mechanism)

Enhancing the agricultural input purchasing power of farmers and lowering food prices through higher production via incentives, such as direct subsidies, tax reductions, and providing credit, play a pivotal role in eradicating farmers' inabilities to acquire the necessary agricultural inputs. In 2002, China introduced direct grain subsidies, and improved its seed subsidies, agricultural machinery subsidies, and comprehensive direct subsidies for agricultural materials. In 2004, China cut the protracted policy of taxing rural households and officially began subsidizing smallholder farmers, agricultural operation organizations, and financial institutions for the purchase of agricultural machinery. Various mechanization subsidies have also been enacted to support the distribution, production, marketing, inspection, after-sales service, and training of the end-users of agricultural machines. The government of China decided to provide agricultural machinery subsidies aimed at (1) establishing a modern agriculture industry, (2) reducing rural–urban income inequality by increasing farmers' income, and (3) maintaining food self-sufficiency through enhancing the agricultural labor productivity.

There are various drivers for the implementation of agricultural machinery purchase subsidies. For instance, Ref. [21] revealed that the drivers of agricultural machinery subsidies were the economic growth of the non-agricultural sector, the geographic dispersion of agricultural commodity sectors, and the demand for food self-sufficiency. They also highlighted that China's ascension into the WTO had a significant impact on the rapid growth of the agricultural subsidy rates.

The agricultural machinery purchase subsidy provided substantial benefits for China's rural development. The subsidy improved the comprehensive mechanization levels of crop cultivation and harvesting in China. The subsidy highly promoted the transfer of surplus rural labor to the urban industrialized areas and the emerging rural industrial areas. Moreover, the subsidy improved the technological progress in mechanization and it also mobilized many farmers' enthusiasm for purchasing agricultural machinery. The implementation of the agricultural machinery purchase subsidy policy also induced the advancement of agricultural machinery and agronomic integration, socialized agricultural machinery services, technology promotion, education and training, and supervision and management practices.

However, the agricultural subsidy program has faced various problems. These include the small scale of funds for agricultural machinery subsidies, a low coverage of agricultural machinery subsidies, limited types of subsidized machinery, a limited variety of agricultural machinery subsidies, low subsidies for new agricultural machinery, and lagging public service capabilities in the agricultural machinery sector. The main causes of problems during the implementation stage are highly associated with the low proportion of financial investment in agriculture and agricultural machinery, a low investment in mechanization administrative expenses, the lagging public service capabilities of the agricultural machinery sector, and the lagging investment and development of mechanization promotion training. Moreover, the implementation stage cannot not fully answer the questions such as Who, How, When, and Where the subsidies should be given. Researchers have revealed that the subsidies did not achieve their intended goals. For instance, Huang. J et al. [35] (2013) found that subsidies were given to the land contractors who were in charge of managing and using the land, while the tillers received only a small proportion of the subsidies, thus, the subsidies had little impact on the farmers' incomes.

- Factor 2. Readjusting farmland policies

China has made continuous land tenure reforms since the establishment of the People's Republic of China in 1949 because the struggle against poverty, food insecurity, and other socio-economic problems was highly linked to the establishment of a proper land tenure system. With this stand, the success of mechanization is fundamentally dependent on the relationship between the rural people and their farmlands; thus, there must be a harmonious relationship between land tenure and agricultural mechanization. Before substituting animal and human power with agricultural machines, the size of the farmland and the rights of farmers should be ascertained; therefore, It is critical to investigate the driving effects of the land tenure system on mechanization in China. We examine the major land tenure policy reform conducted in China in the following section.

After establishing the modern People's Republic of China in 1949, Mao's government abolished landlords and the royal family-based land tenure system and replaced it with the people's commune system. Farmers were the workers on large communal farms, which were managed by an inefficient centralized management system that was often corrupt. The major source of power for the farming operations was predominantly from peasant workers and animals. Only a small number of inefficient tractors were employed in production (predominantly at the plowing stage) on the large community farms and the state monopolized the overall system. In general, the commune system featured a complete top-down management structure which was a complete disaster for developing mechanization in the country; however, there was a need to expand the utilization of farm machinery within the government plan. This highlighted the need to change the overall agricultural system, including a power source substitution to boost the labor productivity.

One of the central issues of the 1978 reform and the opening-up of the policy involved dismantling the people's commune system and establishing the "Household Responsibility System (HRS)". The HRS was a land tenure system in which farmers received land and other means of production based on the size of their families and farmland was disseminated to peasant households according to the proportion of labor. The system offered farmers the chance to become a relatively independent economic entity and as a result, farmers' incomes increased at a rapid rate, and the agricultural product outputs sky-rocketed. The system pushed for farmlands to be divided into smaller plots in order to offer a fair distribution of the limited farmland resources to the enormous number of China's peasant population.

Studies show that the HRS had both positive and negative impacts on mechanization. The system allowed farmers to make decisions on their farmland plots including the decision to use farm machinery as needed and the farm machinery was small-scale to fit the small-sized land plots. The system also offered farmers the right to transfer their farmland plots. This gave the hope that land transfers would speed up the creation of moderate and large farmland plots which could then accommodate large-scale farm machinery; however,

due to the existence of surplus rural labor, the farmland transfer did not lead to larger-scale agriculture as was expected, but rather, small-scale mechanization was dramatically increased on the smaller-scale fractions of farmland. The government accepted the existing situation and induced the development of small-scale farm machinery, while the HRS penetrated the system resulting from the lack of farm machinery in the people's commune system, and thus provided the starting point for replacing the human- and animal-power-based agricultural operations with small machine-based farming operations. Agricultural mechanization was found to be a solution for harmonizing farmland transfer by filling the gap generated by the lack of labor via a transfer of the surplus labor.

In 2014, agricultural land rights in China were divided into three separate rights: management rights, ownership rights and usage rights. This division was formulated for the sake of facilitating the farmland transfer. This was because the agricultural labor had largely declined and so large-scale mechanization could easily gain purchase as the farmland transfer market was expanded throughout the nation. The pre-conditions to fully apply moderate and large-scale modern agriculture operations were to create a condition of farmland transfer to a moderate-scale land size and to scale the management system and technology (mostly agricultural machines) to fit. The idea of allowing farmland transfer has been the foundation for mechanization implementation, since the optimum benefits from farm machines come from scale operations. Proper farmland transfer involves creating more moderate large-scale farms, so that more high-efficiency large-scale machines can then be employed. Farmland transfer is conducive to solving and realizing the optimal allocation and combination of land, labor, capital, technology, information, and other production factors, and it is conducive to the development of moderate-scale operations. The success of transforming the system into one of moderate and large-scale agriculture largely relies on the achievement of applying large-scale machinery through various scale operation measurements.

- Factor 3. Practicing scale-appropriate agricultural machinery theory

Previous studies have given less emphasis to mechanizing small-scale agricultural production. The efficiency of small-scale farming cannot provide enough food for the growing population because poor smallholder farmers have less capability to indulge in capital investment. Moreover, smallholder farmers are unable to gain from operations at scale; however, some studies have argued that small-scale agriculture has a decisive role for the growing population as it only requires affordable inputs from farmers and is easy to operate with the available resources [46,47]. It is believed that large-scale agriculture can create the jobs, goods and services needed for emerging economies [46], while there is a perception that small-scale agriculture can only result in farmers obtaining subsistence levels of production with no surplus, unable to produce enough food for local markets [48].

In recent years, the tremendous role of small farms in the modern economy has received greater recognition. In 2014, the FAO declared the fundamental role of small-scale farming to be at the center of regional, national, and global policies. Small-scale agriculture has a significant advantage such as utilizing natural resources in a sustainable manner [49]. Meanwhile, the concept of small-scale agriculture is commonly linked with the production of crops on a small farmland plot without using advanced and expensive technologies. This leads to the impossibility of innovating and utilizing small-scale agricultural machinery based on the scale of the management or the size of the farmland. There is also misinformation with the term "small-scale agriculture" not being properly defined. It is based on the size of the farmland plot, rather than the farmers' small-scale efficiency level, lack of sufficient income, or a low level of technical inputs.

China is a country that has practically proven the ability for small-scale agriculture to produce surplus crops for both the domestic and the international market. China's agriculture is predominantly small-scale, but this does not necessarily lead to lower efficiency or effectiveness of its agricultural production. China's small-scale agricultural industry is not like those operating in some developing countries such as those in sub-Saharan Africa

where, because the agriculture system is small-scale, the efficiency and technology levels are also lower.

China has practiced a scale-appropriate approach to make the best out of small-scale mechanization. Having a small farmland size does not prevent mechanization development if proper mechanization services are available [28] and small-scale agricultural machines have tremendous benefits for China's agriculture system. Firstly, they are cost-effective. Farmers can afford to purchase these machines and can access the market without huge investments. Secondly, small-scale agricultural machines are appropriate for the vast majority of farmland plots as most of the farmland areas are small and fragmented and need small-scale machines to provide an optimum crop production. Thirdly, farmers can operate small-scale agricultural machines with only a basic level of necessary skill and knowledge, and fourthly, the management system is easy to navigate for small-scale agricultural machines.

■ Factor 4. Promulgation of the agricultural mechanization law

China formulated its mechanization law in 2004. The main aim of the mechanization law was to push farmers, agricultural producers, and operations organizations to utilize advanced agricultural machinery. This law laid a legal foundation making it possible for an all-out implementation of mechanization for grain production. The law stated the procedures and measures required for the government in its implementation of mechanization policies for the production, inspection, supply, after-sales service, and joint-utilization of agricultural machines. The law defined the tasks and duties of the national government, the provincial governments, research institutions, agricultural machinery producers, service providers, and local governments. For instance, article seven states that governments at or above the provincial level shall organize relevant units in terms of planning, organizing, financing and promoting advanced and applicable agriculture machinery.

Though the support of mechanization by the law was highly encouraged, the first law drafted in 2004 had various gaps and limitations. Firstly, insufficient after-sales service hindered the practice of the principle of the law. This mainly occurred due to a lack of technical experts and the difficulties of obtaining spare parts in local markets. As a result, maintenance was a slow and laborious process. Secondly, due to the presence of a large number of smallholder farmers, the subsidy was predominantly offered for small-scale machinery purchases.

The lack of supervision and inadequate legal basis for the comprehensive safety of agricultural mechanical vehicles has caused a deterioration in the quality development of mechanization. The lack of pre-and post-sale supervision has resulted in a poor quality and unsafe performance of the agricultural machinery products. Moreover, though the law defines the measures to promote mechanization development, gaps have been seen in the allocation of finance, tax relief, bank loans, agricultural machinery operation income, machinery oil preferential subsidies, and other policy measures. These all indicate a need to amend the law in order to realize advanced agricultural mechanization in China.

The law provides various outcomes for its users and the central government administration on mechanization. For instance, it greatly helps to maintain personal safety, agricultural product quality safety, and environmental protection. In general, the mechanization law provides benefits such as maintaining personal safety, maintaining a high quality of agricultural machinery, clearly defining which machinery is necessary and avoiding unnecessary machinery, guiding the conduct of agricultural machinery tests and timely appraisals, encouraging a cross-region operation of agricultural machinery use, aiding prompt access to repair services, facilitating technological mechanization innovation, and enhancing the research and development of agricultural machinery through methods including tax policies and subsidies.

■ Factor 5. Agricultural machinery hiring service provision models in China

The capability of smallholder farmers to access and own agricultural machines is hindered by various factors such as having a low income, market distortion, and other

intrinsic and extrinsic factors [6,15]. Smallholder farmers access agricultural machines in three ways. First, farmers may have the purchasing power to buy the machines for themselves. Second, the government supports farmers in the form of agricultural machinery subsidies to purchase machinery, and third, farmers can access agricultural machines via custom hiring services [6]. Most smallholder farmers, however, are unable to purchase machinery themselves. The agricultural machinery subsidy assists smallholder farmers in the short term and is suitable for countries economically strong enough to provide direct subsidies (e.g., China since 2004), but relying on subsidies will likely reduce labor productivity. On the other hand, a custom machinery rental service system is emerging as a new agricultural machinery business model established to compensate for the low machine purchasing power of smallholder farmers.

Agricultural machine rental service providers vary across different countries and regions. For instance, in Bangladesh, the agricultural machinery service provider is a lead farmer, one with a relatively high education level, credit availability, and risk-taking attitude [50]. This service provision system assists Bangladesh to cultivate more than 80% of its farmland. The lead farmers who own the machines can earn additional income through renting their machines to other farmers. In Myanmar, a vibrant, informal private sector dominates the outsourcing services market [28]. In countries such as Mexico, the government has established machine-hire centers in the form of initiatives to provide the appropriate machines to farmers [1]. In Senegal and Mali, international foundations have been facilitating the establishment of mechanization service centers through connecting importers, exporters, and local manufacturers. Meanwhile, in some low-income countries, such as Zimbabwe, international organizations facilitate machinery rental service systems by providing various rental business models including machine rental providers that can access credit by connecting with financial institutions [1].

China has adopted the machine rental services model since 2004 [6]. The sky-rocketing growth of these machine rental markets in rural areas enables smallholder farmers to access the necessary agricultural machines and the agricultural machinery rental service providers are companies, special agents, agricultural cooperatives, other farmers, and governmental institutions. In addition to the local machine rental service providers, cross-regional machine mechanization service providers induce the application of agricultural machines in formerly under-served areas of the countryside [51].

Cheng (2017) [52] explains the four forms of mechanization service in China. First, the trans-regional mechanization operation service is one in which cooperatives provide mechanization rental services to both intra-provincial regions and external-provincial regions and is intended to provide services to regions that lack agricultural machines. Second, an a la carte mechanization operation service is one where mechanization services are used by farmers who are involved in off-farm employment in nearby regions, and through which the farmers can rent agricultural machines based on their preferences. The third is a one-stop mechanization operation service, which is a form of machine service in which farmer cooperatives provide the whole mechanization operation services during the production season and farmers pay a service fee but the harvested crops belong entirely to the farmers. Fourth, the land leasing and contracting mechanization operation service is one in which farmers contractually lease their lands directly to cooperatives who can cultivate the farmland using their heavier machinery, and through which the farmers can obtain benefits in the form of crops or cash payments.

Researchers have investigated the positive and negative effects of agricultural machinery rental services in China. For instance, Qiu et al., 2021. [53] stated that mechanization serviced increase the number of farmers who operate moderate and large farms by inducing the exit of smallholder farmers from agricultural production, through both land abandonment and the renting-out of their land. This indicates that mechanization services induce a land rental market for agricultural scale operations; however, smallholder farmers are triggered to exit agricultural production due to the competing interests in the rented farms from large farm operators and the increase in mechanization service prices. Moreover, Yi

et al. (2019) [54] showed that smallholder farmers accessing agricultural machines through mechanization service providers improve their productivity and profitability but that there is no effect on crop yields. They also revealed that the benefits of smallholder farmers accessing farm machines through mechanization service rental providers are smaller than for those who own farm machines. Ref. [53] found that smallholder farmers tended to utilize more labor while farmers with large farms tended to invest in self-owned machinery assets.

Across the country, the development of machine hiring services is hampered by a market failure that limits access to high-quality mechanization services. Moreover, the mechanization services are limited to specific crop types and agricultural practices, such as rice and wheat and plowing and harvesting, respectively. In some regions, the price of mechanization services is more expensive than the farmers' incomes and the involvement of mechanization service providers other than smallholder farmers creates competitiveness in the market. Smallholder farmers have a lower capacity to compete in the mechanization service rental market [55]; therefore, a new strategy is needed to make mechanization rental services more accessible to smallholder farmers to benefit them in the long term.

7. Conclusions and Policy Implications

This paper examines the development of agricultural mechanization in China and provides evidence on how smallholder farmers access agricultural machines. Mechanization in China has rapidly expanded in the last four decades. Previous studies have stated that the full benefit of mechanization can be obtained only by applying it to large-scale agriculture. In this paper, however, we find that China has shown successful mechanization in small-scale agriculture through applying multidimensional policies, strategies, and incentive measures. Scaling up the agricultural production through farmland consolidation, large-scale agricultural machinery application, and scaled service management is not the only benefit to be gained from mechanization. Instead, applying small-scale agricultural machines to small farmland, i.e., scale-appropriate mechanization, plays a vital role in improving food security, eradicating rural poverty, promoting a healthy labor allocation, creating an agricultural division of labor, and contributing to national economic development.

Based on the above investigations, developing countries in the infant stages of mechanization with a large number of smallholder farmers can derive the following fundamental lessons regarding the mechanization of small-scale agriculture:

- The foundation of mechanization development should rely on a self-reliance system. The establishment of a domestic/local agricultural machinery manufacturing industry should be the priority for mechanization development. Governments need to encourage local manufacturers through various incentives. Moreover, cultivating local, self-driven, farm-machine innovators, operators, and domestic mechanization initiatives triggers the rapid application of agricultural machines.
- Farmer service cooperatives that hire out machinery represent a proper business model that enables smallholder farmers to access machinery for their requirements at a reasonable price. The government and other relevant institutions should take measures to empower those cooperative service providers through incentives or other supporting mechanisms.
- Mechanization institutions should be established at all levels. In China, mechanization institutions are established from the ministry down to the district level. The establishment of a strong institution will enable a government to have clear and attainable policies and strategies.
- Training institutions such as universities should closely work with the farmers, the policymakers and other stakeholders to facilitate a rapid introduction of agricultural machines.
- An appropriate mechanization theory is the key to inducing the rapid growth of mechanization in small-scale agriculture. Agricultural machines suited to local conditions such as the land size, the slope of the land, characteristics of the soil, crop type, or with

a cost-effectiveness for farmers and lower emission rates will influence the decision to adopt machines in small-scale agriculture.

- ➢ The successful application of agricultural machinery requires strong, target-oriented, pro-farmer policies with effective leadership strategies. Moreover, the mixed market model is a powerful system for the rapid introduction of agricultural machines into small farms. Laws, subsidy policies, and incentives for private agricultural machine rental service providers are all effective mechanisms to enhance the accessibility of agricultural machines for smallholder farmers.
- ➢ Mechanization development policies, strategies, or programs need to integrate the land–labor–machine nexus because farmland scale and the supply of labor are essential to promote mechanization development.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14137964/s1.

Author Contributions: Conceptualization, W.L., M.C. and F.Z.; methodology, W.L.; software, W.L. and M.C.; validation, M.C. and F.Z.; formal analysis, W.L.; investigation, F.Z.; resources, F.Z.; data curation, W.L.; writing—original draft preparation, W.L. and M.C.; writing—review and editing, W.L. and M.C.; visualization, F.Z. and M.C.; supervision, F.Z.; project administration, F.Z.; funding acquisition, F.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by a key project of the Hunan Provincial Social Science Achievements Evaluation Committee, China (Grant No. XSP21ZDI023).

Data Availability Statement: Not applicable.

Acknowledgments: We thank very much the Hunan Provincial Social Science Achievements Evaluation Committee for supporting the completion of this work.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

References

1. Van Loon, J.; Woltering, L.; Krupnik, T.J.; Baudron, F.; Boa, M.; Govaerts, B. Scaling agricultural mecha-nization ser-vices in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America. *Agric. Syst.* **2020**, *180*, 102792. [CrossRef] [PubMed]
2. Woltering, L.; Fehlenberg, K.; Gerard, B.; Ubels, J.; Cooley, L. Scaling—From "reaching many" to sustainable systems change at scale: A critical shift in mindset. *Agric. Syst.* **2019**, *176*, 102652. [CrossRef]
3. Belton, B.; Filipski, M. Rural transformation in central Myanmar: By how much, and for whom? *J. Rural Stud.* **2019**, *67*, 166–176. [CrossRef]
4. Qiao, F. Increasing wage, mechanization, and agriculture production in China. *China Econ. Rev.* **2017**, *46*, 249–260. [CrossRef]
5. Felipe, J.; Bayudan-Dacuycuy, C.; Lanzafame, M. The declining share of agricultural employment in China: How fast? *Struct. Change Econ. Dyn.* **2016**, *37*, 127–137. [CrossRef]
6. Zhang, X.; Yang, J.; Thomas, R. Mechanization outsourcing clusters and division of labor in Chinese agriculture. *China Econ. Rev.* **2017**, *43*, 184–195. [CrossRef]
7. Lu, F.M. The Role of Agricultural Mechanization in the Modernization of Asian Agriculture: Taiwan's Experience. *Eng. Agric. Environ. Food* **2009**, *2*, 124–131. [CrossRef]
8. Li, F.; Feng, S.; Lu, H.; Qu, F.; D'Haese, M. How do non-farm employment and agricultural mechanization impact on large-scale farming? A spatial panel data analysis from Jiangsu Province, China. *Land Use Policy* **2021**, *107*, 105517. [CrossRef]
9. Takeshima, H.; Hatzenbuehler, P.L.; Edeh, H.O. Effects of agricultural mechanization on economies of scope in crop production in Nigeria. *Agric. Syst.* **2020**, *177*, 102691. [CrossRef]
10. Van den Berg, M.M.; Hengsdijk, H.; Wolf, J.; van Ittersum, M.K.; Guanghuo, W.; Roetter, R.P. The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. *Agric. Syst.* **2007**, *94*, 841–850. [CrossRef]
11. Wang, X.; Yamauchi, F.; Huang, J.; Rozelle, S. What constrains mechanization in Chinese agriculture? Role of farm size and fragmentation. *China Econ. Rev.* **2020**, *62*, 101221. [CrossRef]
12. Elagib, N.A.; Khalifa, M.; Rahma, A.E.; Babker, Z.; Gamaledin, S.I. Performance of major mechanized rainfed agricultural production in Sudan: Sorghum vulnerability and resilience to climate since 1970. *Agric. For. Meteorol.* **2019**, *276*, 107640. [CrossRef]

13. Nepal, R.; Thapa, G.B. Determinants of agricultural commercialization and mechanization in the hinterland of a city in Nepal. *Appl. Geogr.* **2009**, *29*, 377–389. [CrossRef]
14. Paudel, G.P.; Bahadur, D.K.C.; Rahut, D.B.; Justice, S.E.; McDonald, A.J. Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. *Land Use Policy* **2019**, *85*, 104–113. [CrossRef] [PubMed]
15. Aryal, J.P.; Rahut, D.B.; Thapa, G.; Simtowe, F. Mechanization of small-scale farms in South Asia: Empirical evidence derived from farm households survey. *Technol. Soc.* **2021**, *65*, 101591. [CrossRef]
16. Gong, B. Agricultural productivity convergence in China. *China Econ. Rev.* **2020**, *60*, 101423. [CrossRef]
17. Zhang, Y.; Diao, X. The changing role of agriculture with economic structural change—The case of China. *China Econ. Rev.* **2020**, *62*, 101504. [CrossRef]
18. Wang, X.; Yamauchi, F.; Otsuka, K.; Huang, J. Wage Growth, Landholding, and Mechanization in Chinese Agriculture. *World Dev.* **2016**, *86*, 30–45. [CrossRef]
19. Wen, F.; Yang, Z.; Ou, Y.; Zou, X.; Duan, J. "Government-Industry-University-Research- Promotion" Collaborative Innovation Mechanism Construction to Promote the Development of Agricultural Machinery Technology. *IFAC-PapersOnLine* **2018**, *51*, 552–559. [CrossRef]
20. Li, W.; Wei, X.; Zhu, R.; Guo, K. Study on Factors Affecting the Agricultural Mechanization Level in China Based on Structural Equation Modeling. *Sustainability* **2019**, *11*, 51. [CrossRef]
21. Lopez, R.A.; He, X.; de Falcis, E. What Drives China's New Agricultural Subsidies? *World Dev.* **2017**, *93*, 279–292. [CrossRef]
22. Shuqi, S.; Jiasheng, W.; Dongwei, W. Development of Agricultural Mechanization in China and Its Current Strategic Focus. *Agric. Mach. Technol.* **2019**, *13*, 4–7. [CrossRef]
23. Shi, M.; Paudel, K.P.; Chen, F. Mechanization and efficiency in rice production in China. *J. Integr. Agric.* **2021**, *20*, 1996–2008. [CrossRef]
24. Gao, J.; Song, G.; Sun, X. Does labor migration affect rural land transfer? Evidence from China. *Land Use Policy* **2020**, *99*, 105096. [CrossRef]
25. Tan, S.; Heerink, N.; Qu, F. Land fragmentation and its driving forces in China. *Land Use Policy* **2006**, *23*, 272–285. [CrossRef]
26. Zhang, X.; Yang, J.; Wang, S. China has reached the Lewis turning point. *China Econ. Rev.* **2011**, *22*, 542–554. [CrossRef]
27. Chen, S.; Lan, X. Tractor vs. animal: Rural reforms and technology adoption in China. *J. Dev. Econ.* **2020**, *147*, 102536. [CrossRef]
28. Belton, B.; Win, M.T.; Zhang, X.; Filipski, M. The rapid rise of agricultural mechanization in Myanmar. *Food Policy* **2021**, *101*, 102095. [CrossRef]
29. Nickum, J.E. The politics of agricultural mechanization in China: Benedict Stavis, (Cornell University Press, Ithaca and London, 1978) p. 288, $17.50. *J. Dev. Econ.* **1979**, *6*, 287–290. [CrossRef]
30. Zhou, Y.; Li, X.; Liu, Y. Rural land system reforms in China: History, issues, measures and prospects. *Land Use Policy* **2020**, *91*, 104330. [CrossRef]
31. Liu, Z.; Liu, S.; Jin, H.; Qi, W. Rural population change in China: Spatial differences, driving forces and policy im-plications. *J. Rural Stud.* **2017**, *51*, 189–197. [CrossRef]
32. Kowalewski, D. China and the Soviet Union: A comparative model for analysis. *Stud. Comp. Communism* **1981**, *14*, 279–306. [CrossRef]
33. Bai, Y.; Kung, J.K. The shaping of an institutional choice: Weather shocks, the Great Leap Famine, and agricultural decollectivization in China. *Explor. Econ. Hist.* **2014**, *54*, 1–26. [CrossRef]
34. Hilmy, J. Communists among Us in a Market Economy: Accountancy in the People's Republic of China. *Int. J. Account.* **1999**, *34*, 491–515. [CrossRef]
35. Huang, J.; Wang, X.; Rozelle, S. The subsidization of farming households in China's agriculture. *Food Policy* **2013**, *41*, 124–132. [CrossRef]
36. Rogers, S.; Wilmsen, B.; Han, X.; Wang, Z.J.-H.; Duan, Y.; He, J.; Li, J.; Lin, W.; Wong, C. Scaling up agriculture? The dynamics of land transfer in inland China. *World Dev.* **2021**, *146*, 105563. [CrossRef]
37. Ashayeri, M.S.; Khaledian, M.R.; Kavoosi-Kalashami, M.; Rezaei, M. The economic value of irrigation water in paddy farms is categorized according to mechanization levels in Guilan province, Iran. *Agric. Water Manag.* **2018**, *202*, 195–201. [CrossRef]
38. Kienzle, J.; Ashburner, J.E.; Sims, B.G. Mechanization for Rural Development: A Review of Patterns and Progress from around the World. Food and Agriculture Organization of the United Nations. Plant Production and Protection Division, 2013. Available online: https://www.fao.org/3/i3259e/i3259e (accessed on 1 May 2022).
39. Totin, E.; van Mierlo, B.; Klerkx, L. Scaling practices within agricultural innovation platforms: Between pushing and pulling. *Agric. Syst.* **2020**, *179*, 102764. [CrossRef]
40. Rosenberg, N. Adam Smith on the Division of Labor: Two Views or One? *Economica* **1965**, *32*, 127–139. [CrossRef]
41. Liao, L.; Long, H.; Gao, X.; Ma, E. Effects of land use transitions and rural aging on agricultural production in China's farming area: A perspective from changing labor employing quantity in the planting industry. *Land Use Policy* **2019**, *88*, 104152. [CrossRef]
42. Emami, M.; Almassi, M.; Bakhoda, H.; Kalantari, I. Agricultural mechanization, a key to food security in developing countries: Strategy formulating for Iran. *Agric. Food Sec.* **2018**, *7*, 24. [CrossRef]
43. Huang, M.; Zou, Y. Integrating mechanization with agronomy and breeding to ensure food security in China. *Field Crops Res.* **2018**, *224*, 22–27. [CrossRef]

44. Takeshima, H.; Liu, Y. Smallholder mechanization induced by yield-enhancing biological technologies: Evidence from Nepal and Ghana. *Agric. Syst.* **2020**, *184*, 102914. [CrossRef]
45. Qu, X.; Kojima, D.; Nishihara, Y.; Wu, L.; Ando, M. Can harvest outsourcing services reduce field harvest losses of rice in China? *J. Integr. Agric.* **2021**, *20*, 1396–1406. [CrossRef]
46. Nolte, K.; Ostermeier, M. Labor Market Effects of Large-Scale Agricultural Investment: Conceptual Considerations and Estimated Employment Effects. *World Dev.* **2017**, *98*, 430–446. Available online: https://EconPapers.repec.org/RePEc:eee:wdevel:v:98:y:2017:i:c:p:430-446 (accessed on 1 May 2022). [CrossRef]
47. Araujo-Enciso, S.R.; Pieralli, S.; Pérez Domínguez, I. Introducing uncertainty in a large scale agricultural economic model: A methodological overview. *Comput. Electron. Agric.* **2020**, *178*, 105705. [CrossRef]
48. Stevenson, J.R.; Serraj, R.; Cassman, K.G. Evaluating conservation agriculture for small-scale farmers in Sub-Saharan Africa and South Asia. *Agric. Ecosyst. Environ.* **2014**, *187*, 1–10. [CrossRef]
49. Marcacci, G.; Gremion, J.; Mazenauer, J.; Sori, T.; Kebede, F.; Ewnetu, M.; Christe, P.; Arlettaz, R.; Jacot, A. Large-scale versus small-scale agriculture: Disentangling the relative effects of the farming system and semi-natural habitats on birds' habitat preferences in the Ethiopian highlands. *Agric. Ecosyst. Environ.* **2020**, *289*, 106737. [CrossRef]
50. Rahman, M.M.; Ali, M.R.; Oliver, M.M.H.; Hanif, M.A.; Uddin, M.Z.; Tamim-Ul-Hasan; Saha, K.K.; Islam, M.H.; Moniruzzaman, M. Farm mechanization in Bangladesh: A review of the status, roles, policy, and potentials. *J. Agric. Food Res.* **2021**, *6*, 100225. [CrossRef]
51. Yang, J.; Huang, Z.; Zhang, X.; Reardon, T. The rapid rise of cross-regional agricultural mechanization services in China. *Am. J. Agric. Econ.* **2013**, *95*, 1245–1251. [CrossRef]
52. Cheng, F. Development of Agricultural Mechanization in China. 2017. Available online: https://forum2017.iamo.de/microsites/forum2017.iamo.de/fileadmin/presentations/B5_Fang.pdf (accessed on 1 May 2022).
53. Qiu, T.; Luo, B. Do small farms prefer agricultural mechanization services? Evidence from wheat production in China. *Appl. Econ.* **2021**, *53*, 2962–2973. [CrossRef]
54. Yi, Q.; Chen, M.; Sheng, Y.; Huang, J. Mechanization services, farm productivity and institutional innovation in China. *China Agric. Econ. Rev.* **2019**, *11*, 536–554. [CrossRef]
55. Qiu, T.; Shi, X.; He, Q.; Luo, B. The paradox of developing agricultural mechanization services in China: Supporting or kicking out smallholder farmers? *China Econ. Rev.* **2021**, *69*, 101680. [CrossRef]