TECHNICAL EFFICIENCY OF AGRICULTURE SECTOR IN SHAANXI, CHINA

LI YUJIE

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TECHNICAL EFFICIENCY OF AGRICULTURE SECTOR IN SHAANXI, CHINA

by

LI YUJIE

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LIST OF ABBREVIATIONS

AE	Allocative Efficiency
BCC	Banker - Charnes - Cooper model
CAPCBC	China Agricultural Product Cost-Benefit Compilation
CCR	Charnes - Cooper - Rhodes model
CDRC	China Development and Reform Commission
CE	Cost Efficiency
CPI	Consumer Price Index
CRS	Constant Returns to Scale
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DRS	Decreasing Returns to Scale
FADN	Farm Accounting Data Network
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
FPC	Farmer Professional Cooperatives
GDP	Gross Domestic Product
GECP	Grassland Ecological Compensation Policy
ICT	Information and Communication Technology
IRS	Increasing Returns to Scale
MOA	China Ministry of Agriculture
NBSC	National Bureau of Statistics of China
NIRS	Non-Increasing Returns to Scale
OLS	Ordinary Least Squares
PTE	Pure Technical Efficiency
RMB	Renminbi
RTS	Returns to Scale
SE	Scale Efficiency
SFA	Stochastic Frontier Analysis
TE	Technical Efficiency
TFP	Total Factor Productivity
VRS	Variable Returns to Scale

WTO	World Trade Organization

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KECEKAPAN TEKNIKAL DALAM SEKTOR PERTANIAN DI SHAANXI, CHINA

ABSTRAK

Seiring dengan peningkatan taraf hidup, permintaan terhadap produk pertanian meningkat. Namun, di wilayah Shaanxi, China, pengeluaran pertanian masih belum memenuhi permintaan yang kian meningkat ini. Di Shaanxi, tiada satu pun dari tiga subsektor pertanian—pertanian tanaman, penternakan, dan perikanan — mencapai tahap sara diri. Akibatnya, wilayah ini mesti bergantung kepada wilayah lain atau import untuk memenuhi keperluan pertaniannya. Meningkatkan penggunaan input untuk meningkatkan hasil bukanlah satu amalan yang mampan. Sebaliknya, kerajaan Shaanxi berusaha untuk meningkatkan kecekapan teknikal pertanian, yang melibatkan peningkatan output sambil mengekalkan tingkat input yang sama. Untuk menangani isu ini, kajian ini menyelidik kecekapan teknikal dan punca ketidakcekapan teknikal dalam setiap subsektor pertanian Shaanxi menggunakan Analisis Data Envelopment (DEA) dan regresi Tobit. Dalam subsektor pertanian tanaman di wilayah Shaanxi, terdapat ketidakcekapan teknikal yang ketara. Diperhatikan bahawa timun dan tomato yang ditanam di rumah kaca mempamerkan pulangan skala yang berkurangan dan skor kecekapan teknikal yang lebih rendah berbanding dengan yang ditanam di lapangan terbuka. Ini menunjukkan bahwa pembuat dasar Shaanxi harus mengutamakan promosi kaedah penanaman canggih dan melabur dalam meningkatkan kecekapan penamanan rumah kaca sebelum meningkatkan bilangan rumah kaca. Selain itu, penanaman pelbagai tanaman seperti lobak merah, kubis Cina, dan terung mempunyai potensi untuk meningkatkan pengeluaran keseluruhan secara signifikan dan kecekapan teknikal subsektor

pertanian tanaman Shaanxi. Tanaman ini boleh dipromosikan untuk penanaman di tanah pertanian baru atau digunakan untuk menggantikan tanaman yang kurang cekap. Selanjutnya, mengurangkan harga jualan dan penggunaan baja boleh menyumbang kepada peningkatan kecekapan teknikal. Sementara itu, penggunaan racun perosak boleh membantu melindungi tanaman daripada perosak, seterusnya meningkatkan kecekapan teknikal. Untuk mendukung usaha ini, kerajaan harus menstabilkan harga tanaman dan mengalakkan petani untuk menyertai koperasi profesional petani (FPCs) untuk mencapai pertanian berskala besar dan memperoleh pengetahuan lanjut tentang penggunaan racun perosak dan baja yang tepat. Untuk subsektor penternakan, hasil penemuan mendedahkan bahawa subsektor ternakan Shaanxi mempunyai purata kecekapan teknikal 0.835 (CRS) dan 0.916 (VRS), membayangkan bahawa masih terdapat potensi untuk meningkatkan pengeluaran dengan tingkat input, skala pembiakan, dan teknologi semasa. Walaupun, penternakan lembu tenusu, lembu, dan kambing telah mencapai kecekapan teknikal sepenunya, masih wujud ketidakcekpan teknikal dan skala dalam amalan pembiakan babi dan lapisan. Industri peternakan babi mempamerkan pulangan yang semakin meningkat mengikut skala, dengan operasi penternakan yang lebih besar mencapai kecekapan teknikal yang lebih tinggi. Untuk meningkatkan kecekapan teknikal dalam subsektor penternakan, pentenak harus menumpukan pada penambahbaikan pencegahan perubatan dan wabak, meningkatkan harga jualan, dan mengurangkan kerugian akibat kematian. Shaanxi, sebagai sebuah wilayah pedalaman, tidak memiliki subsektor perikanan yang berkembang maju. Purata kecekapan teknikal dalam perikanan Shaanxi ialah 0.715 (CRS), menunjukkan bahawa kebanyakan bandar tidak beroperasi pada tahap pengeluaran optimummereka. Bandar Weinan adalah pengecualian, menunjukkan kecekapan dalam pengeluaran perikanan.

Analisis pulangan mengikut skala untuk bandar Weinan mendedahkan permerhatian yang patut diberi perhatian terhadap pulangan malar mengikut skala, yang bercanggah dengan galakan dan sokongan kerajaan tempatan terhadap kawasan akuakultur bersepadu. Selain itu, analisis regresi Tobit menunjukkan hubungan positif antara bilangan agensi lanjutan dan kecekapan teknikal. Sebaliknya, kedau-dua pemprosesan dan pengimportan produk perikanan mempunyai kesan negatif terhadap kecekapan teknikal. Secara keseluruhan, hasil kajian ini menekankan kepentingan meningkatkan kecekapan teknikal subsektor pertanian di Shaanxi. Subsektor pertanian tanaman, penternakan, dan perikanan semuanya mempamerkan potensi untuk meningkatkan kecekapan teknikal dalam proses pengeluaran mereka. Penemuan ini juga mengidentifikasi faktor-faktor yang boleh digunakan untuk meningkatkan kecekapan teknikal dalam setiap subsektor ini, dengan itu mengalakkan kemampanan dan pengeluaran pertanian Shaanxi.

TECHNICAL EFFICIENCY OF AGRICULTURE SECTOR IN SHAANXI, CHINA

ABSTRACT

As living standards improve, the demand for agricultural products increases. However, in Shaanxi Province, China, the agricultural production has not met this increasing demand. In Shaanxi, none of the three agricultural subsectors—crop farming, livestock, and fishery—achieve self-sufficiency. Consequently, the province must rely on other regions or imports to meet its agricultural needs. Increasing input utilisation to boost yield is not considered a sustainable practise. Instead, the Shaanxi government aims to improve agricultural technical efficiency, which means increasing output while maintaining the same level of input. To address this issue, this study investigates the technical efficiency and causes of technical inefficiency in Shaanxi's each agriculture subsector using Data Envelopment Analysis (DEA) and Tobit regression. In the crop farming subsector in Shaanxi province, there is notable technical inefficiency. It is noteworthy that the cucumber and tomato grown in the glasshouse exhibit decreasing returns to scale and lower technical efficiency scores compared to those cultivated in open fields. This suggests that Shaanxi policymakers should prioritise promoting advanced cultivation methods and invest in improving the efficiency of glasshouse cultivation before increasing the number of glasshouses. Additionally, the cultivation of diverse crops such as carrots, Chinese cabbage, and eggplants has the potential to significantly enhance the overall production and technical efficiency of the Shaanxi's crop farming subsector. These crops can be promoted for cultivation on new arable land or used to replace less efficient crops. Further, reducing the selling price and fertiliser application can contribute to

increased technical efficiency. Meanwhile, the use of pesticides also helps protect crops from pests, thereby enhancing technical efficiency. To support these efforts, the government should stabilise crop prices and encourage farmers to join farmer professional cooperatives (FPCs) to achieve large-scale farming and acquire further knowledge on the proper use of pesticides and fertilisers. For livestock subsector, the findings reveal that the Shaanxi's livestock subsector has an average technical efficiency of 0.835 (CRS) and 0.916 (VRS), implying potential for increased production with the current level of inputs, breeding scales and technology. While dairy cow, cattle, and goat farming have achieved full technical efficiency, there are still technical and scale inefficiencies in hog and layer farming practices. The hog farming industry exhibits increasing returns to scale, with larger farming operations achieving higher technical efficiency. To enhance technical efficiency in the livestock subsector, farmers should focus on improving medical and epidemic prevention measures, increasing selling prices, and reducing death losses. Being an inland province, Shaanxi does not possess a thriving fishery subsector. The average technical efficiency in Shaanxi's fisheries stands at 0.715 (CRS), indicating that most cities are not operating at their optimal production levels. Weinan City is an exception, demonstrating efficiency in fisheries production. The returns to scale analysis for Weinan City reveals a noteworthy observation of constant returns to scale, which contradicts the local government's encouragement and support for the integrated aquaculture area. Moreover, the Tobit regression analysis indicates a positive relationship between the number of extension agencies and technical efficiency. On the contrary, both the processing and importing of fishery products have negative impacts on technical efficiency. Overall, this study underscores the significance of enhancing the technical efficiency of agriculture subsectors in

Shaanxi. The crop farming, livestock, and fishery subsectors all exhibit potential for enhancing technical efficiencies within their production processes. The findings also highlight factors that can be employed to enhance technical efficiency in each of these three subsectors, thereby promoting sustainability and production of Shaanxi's agriculture.

CHAPTER 1

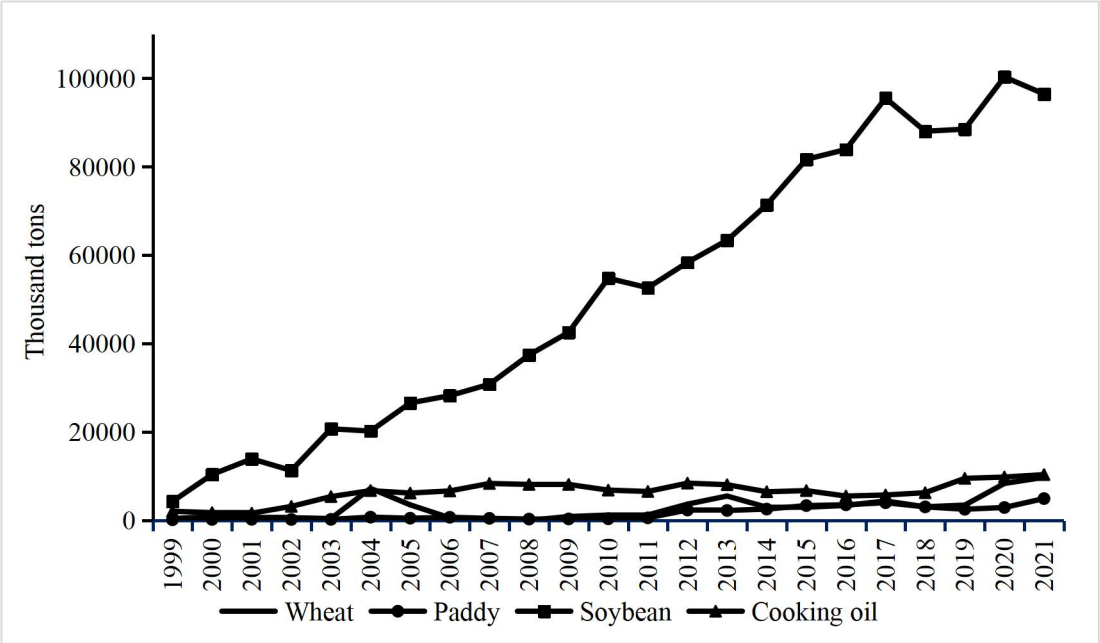
INTRODUCTION

1.1 Introduction

This chapter provides an overview of the agricultural sector's significance in China, focusing on the government's objectives to achieve self-sufficiency in agricultural products. It also details the current status of agricultural subsectors in China and Shaanxi Province, noting that Shaanxi's agricultural practices could be applicable to one-third of the nation. Additionally, this chapter introduces the term “technical efficiency,” which is central to this study. It encompasses the problem statement, research objectives, the significance of the study, and the organization of the research.

1.2 Agriculture Sector in China

China has the largest agriculture sector in the world in terms of both production and land area. However, it is worth nothing that China holds the position of the world’s largest food importer, with a rapidly increasing volume of imported foodstuffs (Jiang, 2020). This dependence on imports primarily attributes to certain agricultural products (Figure 1.1). Foremost among them are imported soybean, which accounts for a significant 60% of the global soybean imports (Gale et al., 2019). Meanwhile, the breeding quantities of hogs, poultry, and fish have increased rapidly, and the consumption of soybeans as animal feed has also risen sharply (Brown, 2012). Followed soybean, the next significant imports include cooking oil (approximately 20%), wheat (4.17%), and paddy (4.17%) (Song & He, 2021). Consequently, China’s food security remains vulnerable due to its reliance on imported food products, indicating a lack of self-sufficiency.



Source: National Bureau of Statistics of China, 2022

Figure 1.1 Major imported agricultural products in China

China President Xi Jinping emphasised this concern of self-sufficiency in food production during the 14th Five-year Development Plan Agricultural Community Conference in March 2022. In his statement, President Xi noted the imperative for China to achieve self-sufficiency in food production. He proposed measures to reduce reliance on food imports (Wang, 2021; Huaxia, 2022b; Ministry of Agriculture, 2022). Pursuing the goal of agricultural self-sufficiency, each province is granted the autonomy to formulate agricultural policies tailored to its unique circumstances, all aimed at improving agriculture efficiency and productivity.

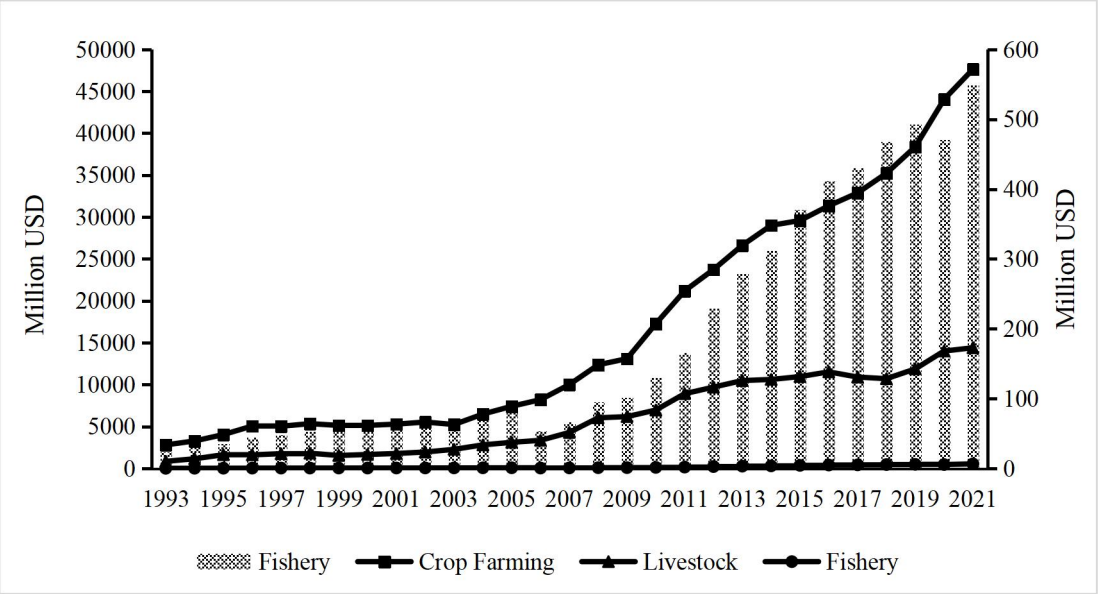
1.3 Agriculture Sector in Shaanxi Province

Shaanxi Province is located in the northwest region of China, encompassing a land area of 20.58 million hectares, which accounts for approximately 2.14% of China's total land area. The province spans various climatic zones, including plateaus, plains, mountains and basins, characterized by four seasonal temperature variations and arid conditions. Within Shaanxi's province, there are four million

hectares of arable land, marked by diverse topography and climate conditions. The cultivation methods and techniques employed in Shaanxi can be applied to approximately 33.49% of the China arable land (Li, 2012).

1.3.1 Crop Farming Subsector

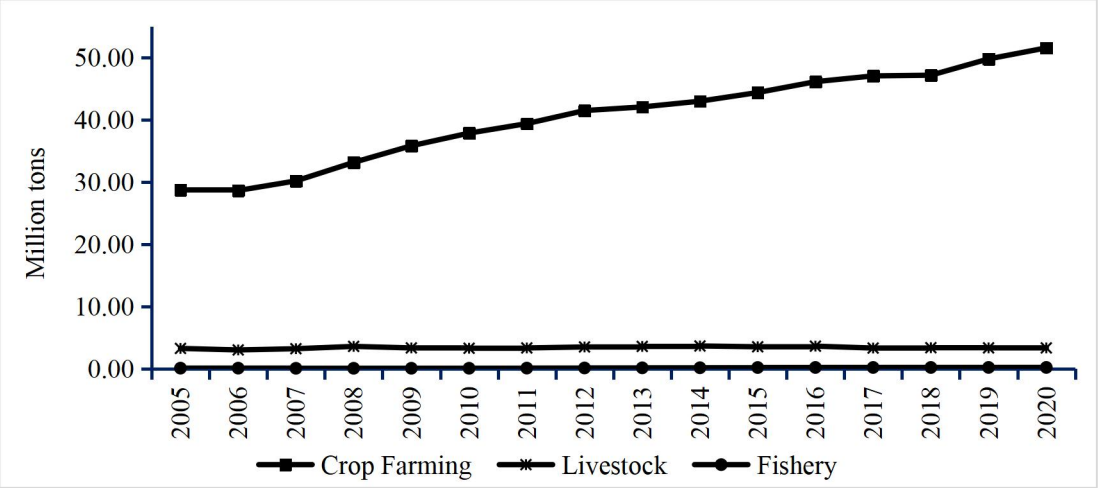
The income structure within Shaanxi's agriculture sector is depicted in Figure 1.2. Notably, the output values of three key agriculture industries have shown a consistent upward trend. Specifically, over the past decade, the fishery subsector has witnessed a remarkable growth, expanding fivefold, the crop farming subsector has tripled, and the livestock subsector has doubled in terms of value. As of the year 2021, crop farming contributes more than three-quarters of the total gross agricultural output value, with livestock accounting for 23%, while fishery production makes a relatively modest contribution of only 1%.



Source: National Bureau of Statistics of China, 2022; author's calculation

Figure 1.2 Output value for three agriculture subsectors in Shaanxi

As depicted in Figure 1.3, when considering production, it is evident that the crop farming subsector is experiencing rapid growth among three subsectors. In contrast, livestock production, encompassing meat, milk and eggs, steadily fluctuates around 3.5 million tons annually. Additionally, production in the fishery subsector has been increasing steadily each year, albeit at a sustained rate, with the total remaining 180 thousand tons.

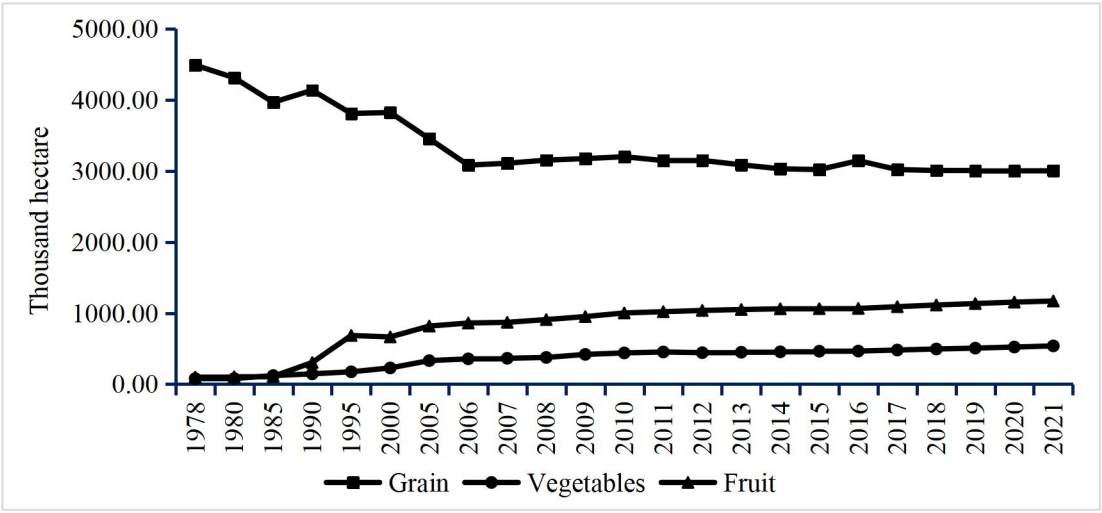


Source: The National Bureau of Statistics of China, 2021

Figure 1.3 Output volume for three agriculture subsectors in Shaanxi

Crop farming subsector stands out as the most prominent contributor to output within the agriculture sector, surpassing other subsector. However, this subsector encounters significant challenges due to the limited availability of arable land resources in Shaanxi. The crop farming subsector in Shaanxi is predominantly characterised by the cultivation of vegetables, fruits, and other high-value-added crops. According to the data presented in Figure 1.4, there has been a consistent decline in the area allocated for grain production in Shaanxi over the years. Conversely, the arable land for vegetables and fruits have exhibited a gradual and consistent growth. A report published by the Bureau of Statistics of China in 2004 highlighted that Shaanxi faced challenges related to grain supply, with production falling short of consumption between 1995 and 2003. According to the National

Bureau of Statistics of China (NBSC, 2004), Shaanxi province saw a surplus in grain production for a mere two out of the nine years under consideration. This limited success poses a significant challenge to the province's goal of achieving complete self-sufficiency in the remaining seven years. Additionally, a study revealed that the grain self-sufficiency rate in Shaanxi Province remained around 85% from 1978 to 2010 (Li, 2012). Since 1998, the arable land dedicated to grain production in Shaanxi has been on the decline due to the implementation of the Returning Farmland to Forest program and the expansion of orchard areas. Feng Yongzhong, an agricultural officer in Shaanxi, has noted that the province stands as the sole province in North China that has not achieved self-sufficiency in grain production. A recent study from 2021 highlighted that the grain self-sufficiency rate in Shaanxi stands at 82%, significantly below the national average of 95% as reported by CNWest in 2023 (CNWest, 2023). This disparity underscores a critical challenge in meeting the national policy target of maintaining a 95% self-sufficiency rate, which is essential for food security. The data highlights an urgent need for Shaanxi to concentrate on enhancing agricultural efficiency. Improving grain production efficiency is essential not only to meet national food security goals but also to ensure the sustainability of local food systems in light of decreasing arable land due to environmental policies.



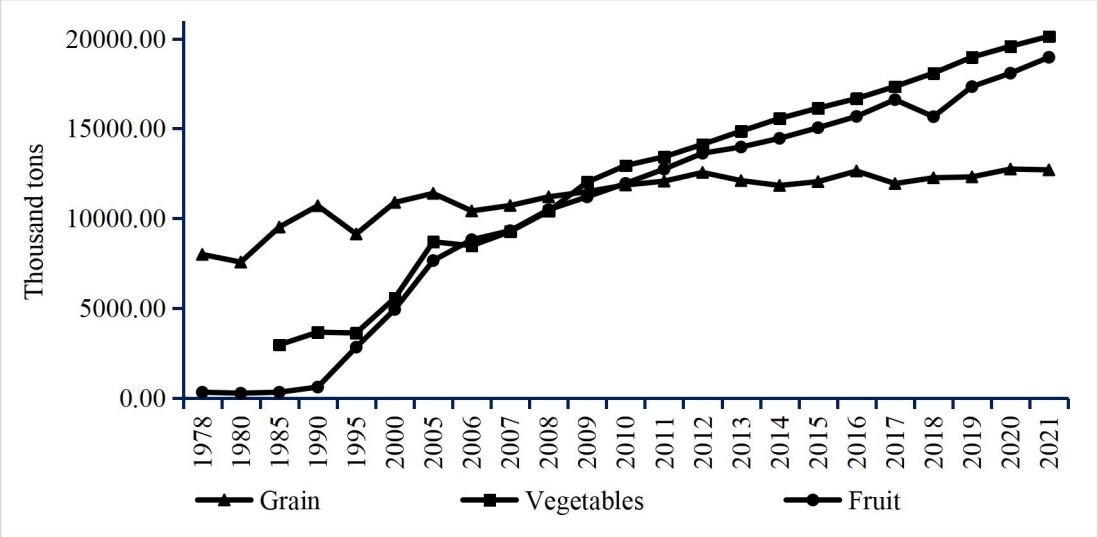
Source: Shaanxi Statistics Yearbook, 2022

Figure 1.4 Planting area in Shaanxi

In contrast, the majority of Shaanxi province relies on a single annual harvest. However, in order to optimise land utilisation through replanting, many farmers have adopted glasshouse farming techniques for cultivating high-value crops such as cucumber and tomato. Additionally, the Shaanxi government recognises the potential of cultivating high-value-added crops, particularly in the vegetable and fruit industries, as a means to alleviate poverty and enhance farmers' income. Consequently, since 1999, the government has strategically adjusted the agricultural structure by converting arable land into orchards and designating the fruit industry as a key sector for local agricultural economic development. Figure 1.4 illustrates that over the span of nine-year, from 1999 to 2007, approximately 210 thousand hectares of grain arable land were converted to fruit cultivation, accounting for 19% of the total reduction in grain arable land. Consequently, the apprehension regarding food insecurity has been heightened due to the decrease in grain planting areas, although the augmentation of vegetable and fruit cultivation has yielded favourable outcomes for farmers' sustenance.

According to the data presented in Figure 1.5, there has been a marginal upward trend in grain production during the previous ten years. Notably, maize production had a more pronounced growth, while the production of other grains remained relatively consistent. In the year of 2010, fruit production in Shaanxi province exceeded the production of both vegetables and grains, emerging as the primary output within the crop f Inefficiency is not only happening in the vegetable industry. As noted previously, the grain output arming subsector. In 2019, as reported by the China Ministry of Agriculture (MOA), Shaanxi Province attained the highest rank in China with fruit planting area, while securing the fourth position in terms of fruit production. Shaanxi has a prominent role in both the domestic apple

production of China and the global apple production industry, making substantial contributions that account for 26.11% of China's apple output and 12.96% of global apple production (Shaanxi Statistics Bureau, 2023; U. S. Department of Agriculture, 2024). Moreover, it plays an important role within the global apple juice manufacturing industry. Shaanxi province holds a prominent position in the kiwifruit industry, accounting for around one-third of global production. It is noteworthy that Shaanxi has the largest kiwifruit orchard in the world (Wang et al., 2019b).



Source: Shaanxi Statistics Yearbook, 2022

Figure 1.5 Output of crop farming products in Shaanxi

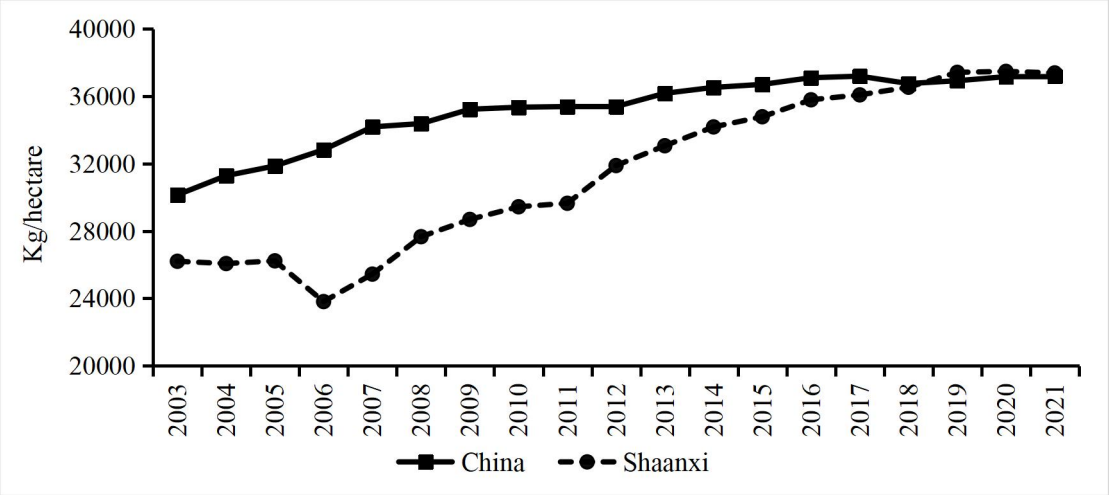
The demand for vegetables has been on the rise due to several factors including continuous population growth, improved urban and rural income, and advancements in processing technology. In Shaanxi Province, the majority of vegetables are locally sourced, primarily to reduce transportation time, costs, and losses. In 2022, The Department of Agriculture and Rural Affairs of Shaanxi Province introduced the "14th Five-Year Plan for the Development of Modern Vegetable Industry in Shaanxi Province". This plan encourages farmers to engage in vegetable cultivation with the aims of enhancing the province's self-sufficiency rate and improving farmers' incomes (Department of Agriculture and Rural Affairs of

Shaanxi Province, 2022). It also emphasises the reduction of fertiliser and pesticides usage. Moreover, the plan aims to promote mechanisation in the vegetable industry and advocate for the establishment of large-scale vegetable plantations to minimise labour costs.

Given the challenges associated with off-season vegetable shortages in Shaanxi Province, the government is actively encouraging farmers to adopt glasshouse cultivation methods. This approach helps mitigate the impact of temperature fluctuations and natural disasters, extends the supply period, and meets the demand for winter vegetables (Shaanxi Government, 2020). Glasshouse cultivation offers advantages such as a shorter production cycle and increased economic benefits, prompting the government to advocate for expanding the area dedicated to glasshouse cultivation to boost vegetable production. Moreover, the most recent "Number One Document" for 2023 released by the Shaanxi Provincial People's Government reiterates the importance of improving productivity in the vegetable industry (Shaanxi Government, 2023).

In 2021, Shaanxi Province recorded a vegetable production of 20.13 million tons, cultivated over an area of 538.48 thousand hectares, resulting in a yield of 37,379.66 kg per hectare (NBSC, 2022). As illustrated in Figure 1.6, there is a discernible upward trajectory in vegetable yield per hectare within Shaanxi, spanning the years from 2003 to 2021, though it remains in proximity to, yet below, the national average. During the three years from 2019 to 2021, Shaanxi's per hectare yield exceeded the national average. However, it is currently uncertain whether this trend will remain stable. Notably, the per capita vegetable consumption in Shaanxi lags the national average by 15.09%, primarily attributable to its substantial population (Wang et al., 2021b). These statistics highlight a persistent imbalance

between vegetable supply and demand in Shaanxi, necessitating the import of vegetables from other regions to meet the demand during certain months, thus indicating existing supply-demand contradictions (Wang et al., 2013). In the year 2021, glasshouse vegetable production and cultivated area constituted only 29% and 40%, respectively, of the province's vegetable industry. These figures fall below the national average (Department of Agriculture and Rural Affairs of Shaanxi Province, 2022). Although vegetable production in Shaanxi has increased over the past decade, yet the pace of this increase has been declining. Additionally, although the cultivation area for vegetables has consistently expanded, the growth rate of yield per hectare has also been declining. These observations suggest the possibility of inefficiencies within Shaanxi's vegetable industry.

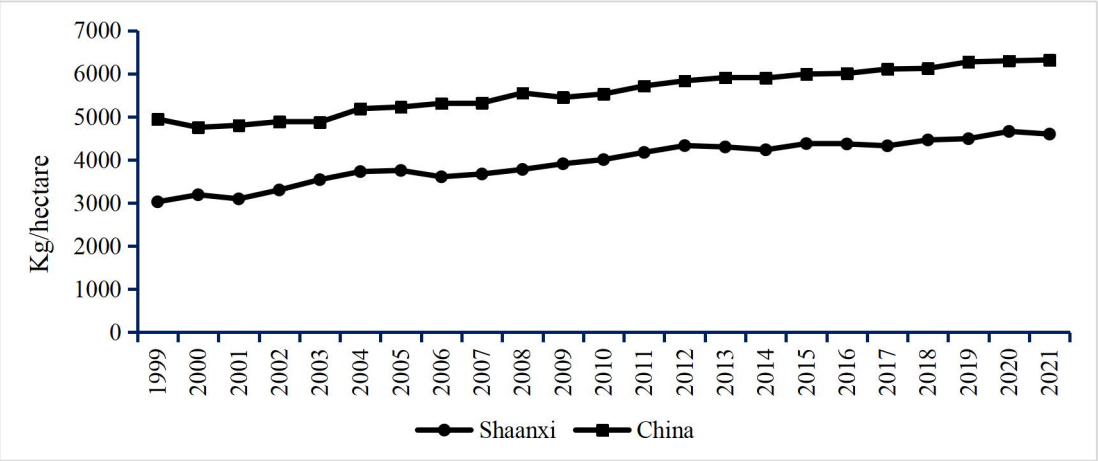


Source: National Bureau of Statistics of China, 2023

Figure 1.6 The comparison of vegetable output per hectare between China and Shaanxi

Inefficiency is not only happening in the vegetable industry. As noted previously, the grain output per capita of Shaanxi residents only accounts for 66.17% of the national average, indicating that Shaanxi's grain production cannot be self-sufficient (NBSC, 2022). Moreover, the ongoing decrease in the area of land dedicated to grain cultivation is leading to increasing pressure on Shaanxi's grain

supply. Figure 1.7 shows that Shaanxi's grain output per area has consistently fallen short of the national average, indicating that the existence of inefficiency in grain production.



Source: National Bureau of Statistics of China, 2022

Figure 1.7 The comparison of grain output per hectare between China and Shaanxi

In 2021, Shaanxi's grain output reached 12.75 million tons, ranking it 19th among the 31 provinces in mainland China and contributing 1.90% to the national grain production. The grain cultivated areas, totaling 3000 thousand hectares, accounts for 2.57% of China's total and rank 16th among all provinces. However, Shaanxi's grain output per area only ranks second from the bottom out of all the provinces (see Table 1.1).

Table 1.1 Grain output per area by provinces in China, 2021

Ranking	Province	Output per area (kg ha^{-1})	Ranking	Province	Output per area (kg ha^{-1})
	National	6133.73	16	Beijing	6332.91
1	Shanghai	8030.99	17	Henan	6224.29
2	Xinjiang	7379.66	18	Jiangxi	6017.47
3	Liaoning	7376.80	19	Anhui	5999.91
4	Jilin	7363.40	20	Hebei	5998.57
5	Jiangsu	7128.36	21	Guangdong	5951.21
6	Heilongjiang	6770.05	22	Tibet	5777.57
7	Tianjin	6724.13	23	Ningxia	5707.64
8	Zhejiang	6697.64	24	Hainan	5609.03
9	Chongqing	6663.26	25	Guangxi	5463.68
10	Hunan	6646.74	26	Yunnan	5135.38

11	Shandong	6637.83	27	Guizhou	5055.44
12	Sichuan	6451.40	28	Gansu	5031.62
13	Fujian	6431.94	29	Shanxi	4764.62
14	Hubei	6365.59	30	Shaanxi	4597.63
15	Inner Mongolia	6333.75	31	Qinghai	3477.08

Source: National Bureau of Statistics of China, 2021

The crop farming subsector in Shaanxi could be facing efficiency challenges as it exhibits lower grain output per area compared to the national average, particularly for soybean and maize (NBSC, 2023a). Although fruit production is relatively high, vegetable production remains insufficient for self-sufficiency. On the other hand, the process of urbanization in Shaanxi, along with initiatives such as the Returning Farmland to Forest projects, has resulted in a decline in the agricultural labour force and a reduction in arable land (Forestry Bureau and Grassland Bureau China, 2020; NBSC, 2022). These circumstances constrain the potential for production improvement through the expansion of planting areas. Therefore, in order to meet the government's food security objectives, Shaanxi must strive to improve agriculture efficiency.

1.3.2 Livestock Subsector

Global demand for livestock products, particularly in China, is increasing due to factors such as population growth, rising incomes, and shifts in lifestyle and dietary preferences (FAO, 2021). According to the National Bureau of Statistics of China (NBSC) in 2022, China livestock subsector produced substantial quantity of various products, including 52.959 million tons of pork, 6.975 million tons of beef, 5.141 million tons of mutton, 24.825 million tons of poultry, 34.088 million tons of eggs, and 36.827 million tons of milk (NBSC, 2023b). China holds a prominent position in global livestock production, ranking first in the production of pork,

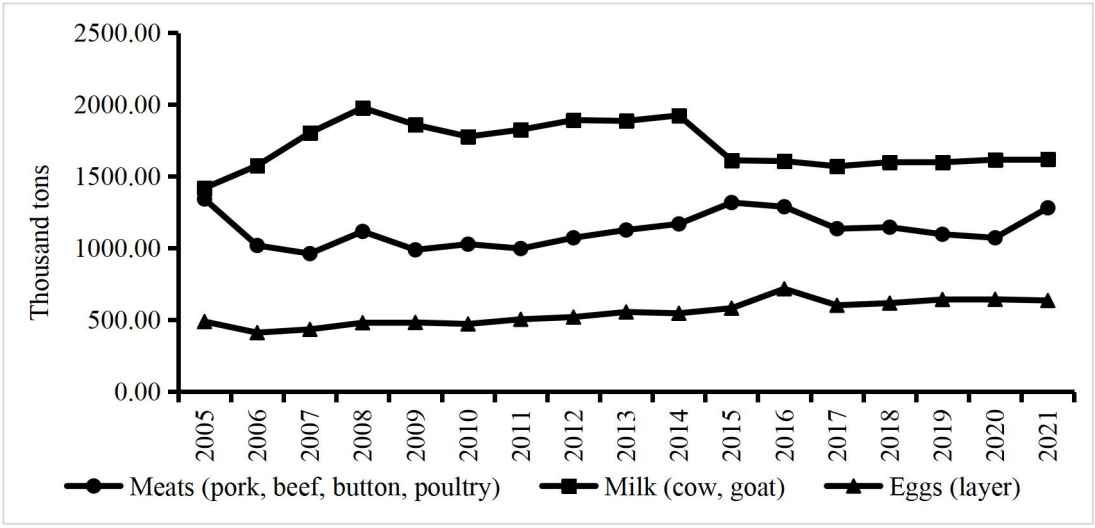
mutton, broiler, and egg, and third in dairy production (FAO, 2022a). Despite the increasing production, China remains the largest importer of livestock products worldwide (FAO, 2022b).

Empirical research has revealed that China's present production of pork, beef, and mutton falls short of satisfying the country's demand (Ding & Xiao, 2014; Liu et al., 2014; Hu et al., 2015; Shi et al., 2015). At 2020, the proportion of imported meat in China's overall meat production reached 12.7%, equivalent to 9.91 million tons, indicating a substantial increase over the previous five years (CISource, 2022). Amid the COVID-19 pandemic, China tightened restrictions on imported food due to the detection of the virus in frozen food products (Cadell, 2020). This situation posed challenges not only for food suppliers and supply chains but also emphasised China's dependence on imported meat and dairy products. China government has incorporated a goal to increase livestock production in its 14th Five-Year Plan (2021-2025), with an expected growth of 15% in meat production (Patton, 2022; Shaanxi MOA, 2022b). The anticipated increase in industrial output could potentially reduce the need for importing livestock, if all the producers can operate at full technical efficient[1].

As of 2021, Shaanxi's livestock subsector ranked 20th out of 31 provinces in mainland China, contributing 21.3% of the agricultural output value. The province produced 1.274 million tons of meat, 634,000 tons of eggs, and 1.619 million tons of dairy products. According to the most recent "14th Five-Year Plan for Livestock and Veterinary Development in Shaanxi" (Shaanxi MOA, 2022a), it is anticipated that there will be an increase in output, with an expected output of 1.8 million tons of meat, 0.8 million tons of eggs and 3 million tons of dairy products by 2025.

[1] Full technical efficient means producing the maximum amount of goods or services possible given the existing technology and input levels.

The livestock subsector plays a significant role in Shaanxi. Shaanxi accounts for 80% of the national goat milk production, and its egg production is crucial for fulfilling the demand of neighbouring provinces (NBSC, 2021). Moreover, pork and milk provide the majority of proteins for Shaanxi residents. However, this industry confronts obstacles such as outbreaks of diseases including African swine fever for hog (Wang et al., 2021a) and avian influenza for layer (Chen et al., 2014), as well as gradually increasing breeding costs. These obstacles may reduce the farmers' enthusiasm and lead to a downsizing of farming operations. Despite these difficulties, the Shaanxi government has been promoting the expansion of livestock production to reduce China's dependence on imported livestock products. As depicted in Figure 1.8, there is a decline in the total output of livestock subsector, particularly meats production, which has been declining since 2015. Milk production has exhibited



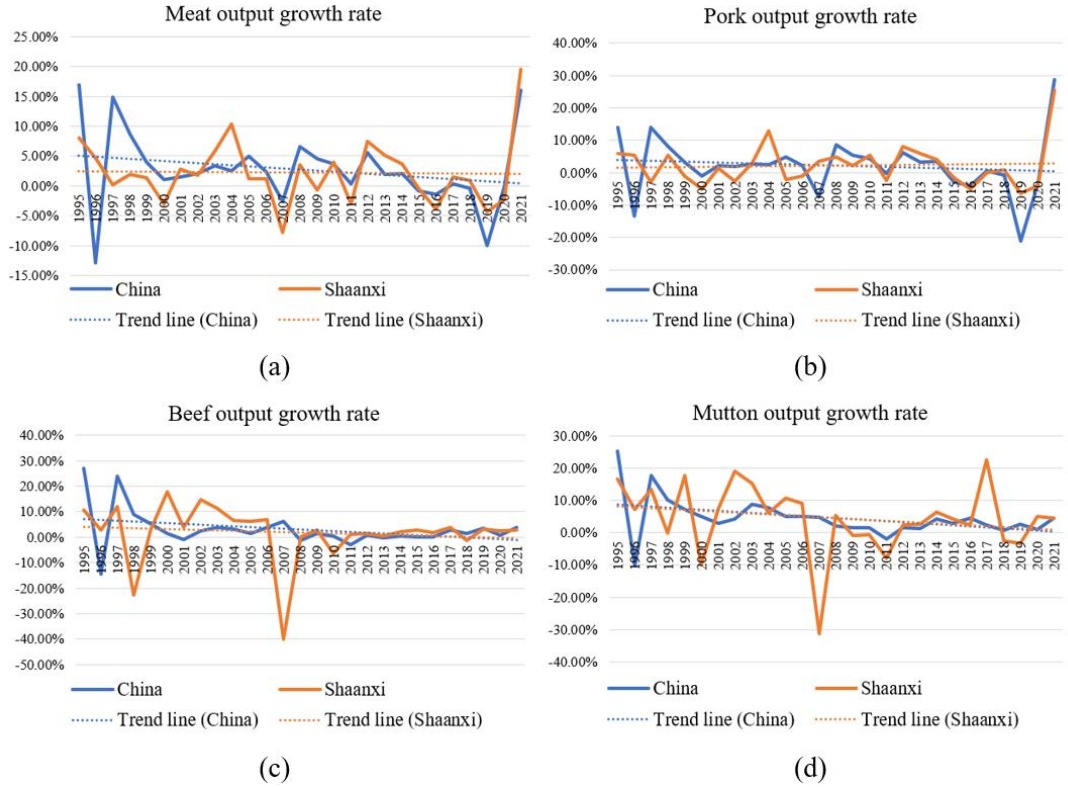
fluctuations, while egg production has been a slight increase over the same period.

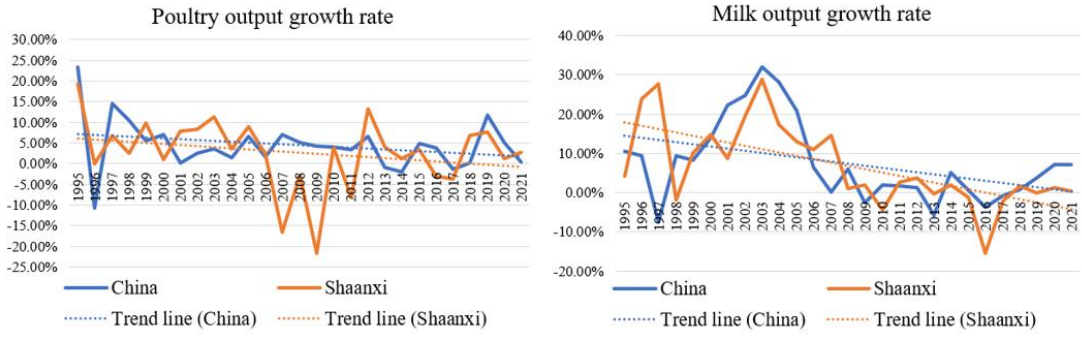
Source: Shaanxi Statistics Yearbook, 2022

Figure 1.8 Output of livestock products in Shaanxi

The livestock subsector does not count the livestock per land area here because the area data is not available to get. So, livestock performance is measured

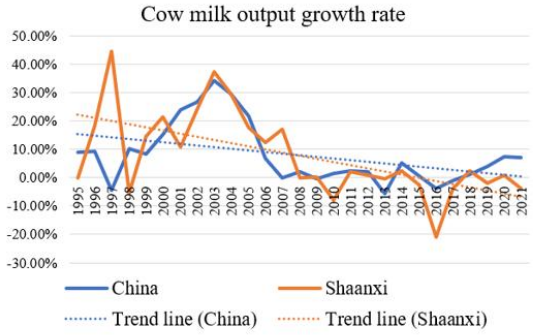
as the output volume growth rate. The rates in both China and Shaanxi are decreasing, as shown in Figure 1.9, yet Shaanxi's meat output growth rate trend line is higher than that of China recently. Moreover, the performance of pork output, beef output, mutton output, and egg output are better than the national average. In comparison, the growth rates of poultry output and milk output (especially cow milk) in recent years are lower than the national average.





(e)

(f)



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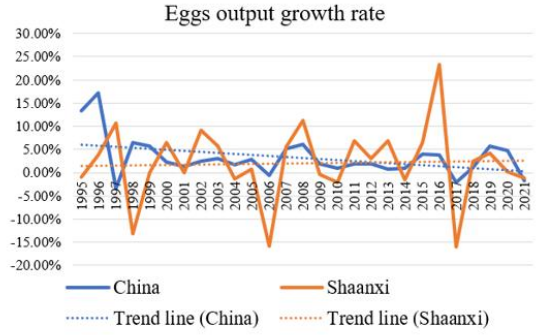
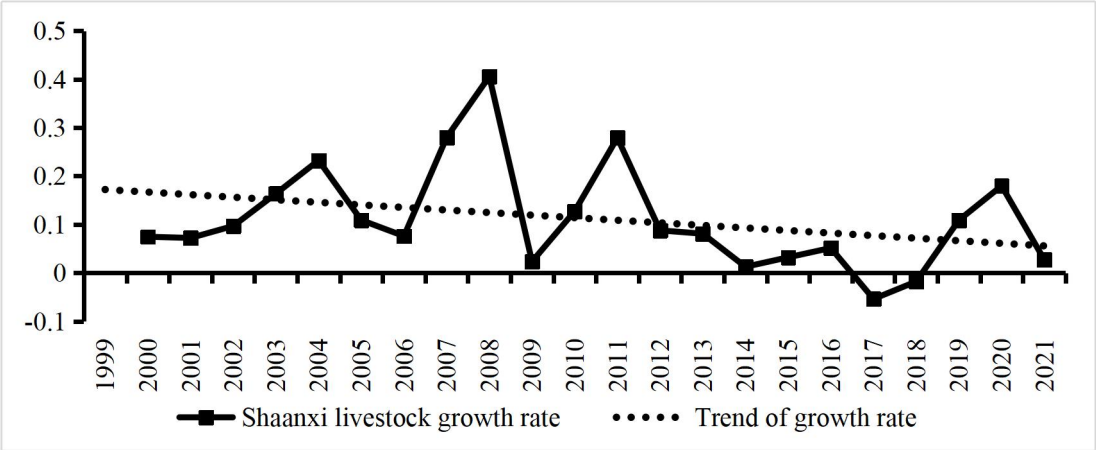


(h)

Source: CEIC Database, 2022; author's calculation
Notes: (a) "Meat" encompasses pork, beef, mutton, poultry, and duck; (e) "Poultry" includes both chicken and duck; (f) "Milk" refers to both cow's milk and goat's milk; (h) "Eggs" include both chicken eggs and duck eggs.

Figure 1.9 The comparison of the growth rate of the livestock subsector between China and Shaanxi

The output of the livestock subsector in Shaanxi increased annually, but the growth rate has shown a decreasing trend year on year (see Figure 1.10). This slower growth may be due to the inefficiency that exists in Shaanxi Livestock industry. Thus, it is important to know whether inefficiency exists in the Shaanxi livestock subsector and to identify the source of inefficiency. Such an understanding would enable producers in the livestock subsector to take necessary steps to improve efficiency and enhance overall subsector performance.



Source: National Bureau of Statistics of China, 2022

Figure 1.10 The growth rate of livestock subsector in Shaanxi

In summary, as the demand for protein increases, the production capacity of China's livestock industry has been unable to meet this growing need. This shortfall has led to an increased reliance on imported products, resulting in a declining trend and underwhelming performance in the sector.

1.3.3 Fishery Subsector

Shaanxi is an inland province, and its fishery largely depends on freshwater aquaculture. The majority of water resources within Shaanxi's territory are part of external river systems, mainly the Yellow River and the Yangtze River. Within Shaanxi, the Yellow River basin covers an area of 13.33 million hectares, contributing to 49% of the total fishery output value in the province. Additionally, the Yangtze River basin within Shaanxi encompasses an area of 7.23 million hectares (Shaanxi Government, 2022b). The geographical environment of the fishery subsector in Shaanxi 10 cities can be categorized into three groups: southern, central, and northern regions. The southern region of Shaanxi, referred to as Shannan, encompasses 34% of the total land area of the province. This region is distinguished

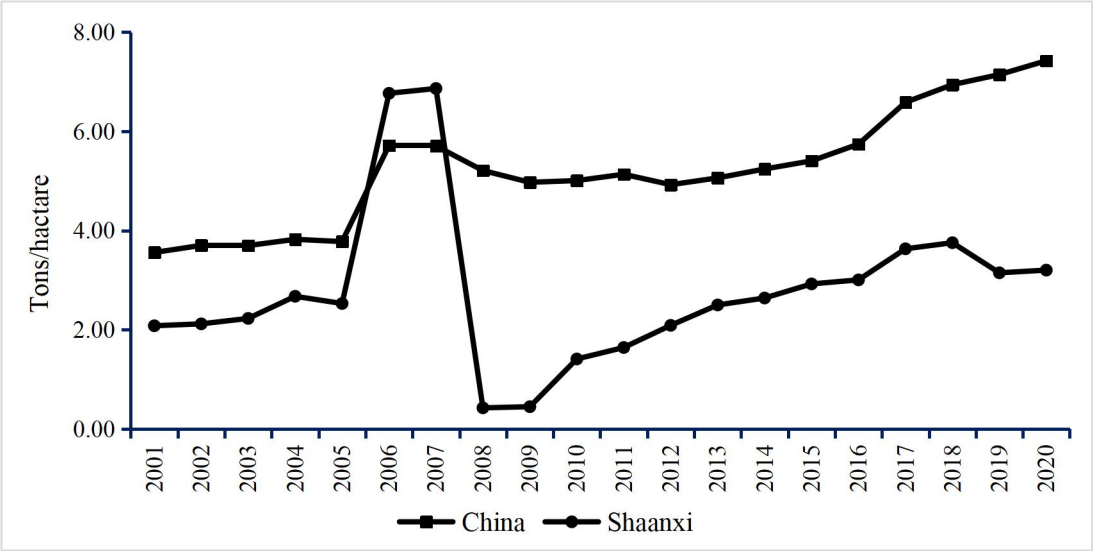
by its abundant water resources, which play a pivotal role in shaping its distinctive fisheries sector. This industry encompasses three cities within southern Shaanxi, such as Ankang, Hanzhong, and Shangluo (see Figure 1.11). Central Shaanxi, also known as the Guanzhong region, covers 26.9% of the total land area of Shaanxi province. This region is characterized by relatively limited water bodies and is composed of five cities: Baoji, Tongchuan, Weinan, Xi'an, and Xianyang. The northern regions of Shaanxi province, particularly Yan'an and Yulin, encompass 39.1% of the total land area of the province. These regions confront a notable deficiency in water resources, thereby exerting a profound influence on the local fisheries environment. According to data from the year 2020, the fishery production in Shaanxi province was distributed as follows: southern Shaanxi accounted for 50.7%, central Shaanxi accounted for 44.4%, and northern Shaanxi accounted for 4.9% of the total production (Shaanxi Statistics Bureau, 2021). Thus, the production of fishery products is majority from central and southern region of Shaanxi.

In Shaanxi province, the aquaculture sector primarily focuses on fish species (93.1%), including common carp (28.1%), grass carp (23.4%), silver carp (19.2%), and perch, while crustaceans constitute a smaller portion (1.5%), comprising shrimp (1.2%) and crabs (0.5%) (Chinese Society of Fisheries et al., 2021; Hu, 2022).

Figure 1.11 Shaanxi map

The per capita aquatic output of Shaanxi province, encompassing finfish, shellfish, and seaweed, amounts to 4.4kg. This figure represents merely one-tenth of the national per capita aquatic output. Freshwater aquaculture accounts for 97% of the fishery in Shaanxi, relying primarily on lakes, reservoirs, and ponds, while capture fishery production accounts for only 3%. According to the China Fishery Statistical Yearbook 2020, the fishery production in the province of Shaanxi in 2019 reached a total of 166.21 thousand tons, accounting for approximately 1.80% of the total fishery production in China. Freshwater aquaculture amounted to 161.20

thousand tons output, covering 51.16 thousand hectares cultivated area, representing 0.53% and 0.72% of the country respectively. Shaanxi freshwater aquaculture mainly relied on cultivating in the pond, which production was 90.38 thousand tons, covering 12.70 thousand hectares waters, representing 56.07% and 24.82% in Shaanxi respectively. The next is the river, which produced 2.92 thousand tons output and covered 1.89 thousand hectares waters, or 1.81% and 3.69% of the total fishery area in Shaanxi. However, the fishery production is insufficient for Shaanxi consumption, and most high-grade fishery products rely on external supply (Zhang, 2005). Moreover, it can be observed from Figure 1.12 that the output per unit area in Shaanxi consistently remains at half of the national average. Conversely, Shaanxi employs 70.03 thousand fishery workers, each with an annual income averaging US $2,363.56 per capita. Although Shaanxi's fishery population constitutes only 0.38% of the national fishery population, their income is approximately 71.30% of the national average income for fishermen. The limited output per unit area fails to incentivise fishermen and hinders the potential for further advancement in Shaanxi's fishery sector. Therefore, considering all these indicators, the fishery subsector in Shaanxi falls below the national standard, highlighting the presence of potential for improvement.



Source: CEIC Database, 2022; China Fishery Statistic Yearbook, 2020; author's calculation

Figure 1.12 The comparison of fishery output per hectare between China and Shaanxi

1.4 Operational Definition of Key Terms

1.4.1 Efficiency

Efficiency is a broad term that measures how well resources are utilised to achieve a certain goal or outcome. It indicates how effectively inputs are transformed into outputs. In economics, the term "efficiency" is generally used to define the ability to produce the optimal output(s) with a given level of input(s), vice versa (Agasisti & Gralka, 2019). It can encompass various aspects, including technical efficiency, allocative efficiency, and cost efficiency (Farrell, 1957). Technical efficiency refers to the ability of a producer to maximize output with a given set of inputs. It measures how effectively inputs are transformed into outputs without any wastage. Allocative efficiency ensures that resources are used where they are most valuable and generate the highest return. Unlike technical efficiency, which focuses on the physical relationship between inputs and outputs, allocative efficiency takes into account the cost and value of inputs and outputs. Cost efficiency combines the

concepts of technical and allocative efficiency by ensuring that resources are not only used effectively (technical efficiency) but are also allocated in a way that minimizes production costs (allocative efficiency). Since farmers' income is not the primary focus of this thesis, it will only examine technical efficiency.

1.4.2 Technical Efficiency

The term technical efficiency is a subset of efficiency. Technical efficiency is a form of efficiency that specifically concentrates on the relationship between inputs and outputs within a production process. According to Farrell (1957), technical efficiency (TE) pertains to achieve optimal output while utilising a given set of inputs and technology, or to reduce the redundant input giving the same output.

The optimal unit, often referred to as "best practice units", serves as the benchmark in performance analysis. This benchmark signifies that other firms have the potential to achieve a similar level of performance as the benchmarked unit. Afterward, these firms are assessed in comparison to the benchmark to ascertain their technical efficiency score, indicating the degree of efficiency in their operations relative to the benchmark (Coelli et al., 2005). Thus, technical efficiency is often expressed as a ratio of the actual output to the optimal potential output.

1.4.3 Technical Inefficiency

Technical inefficiency refers to the differences between the observed output of a product and the maximum potential output that could be produced with the same inputs (Sharma, 1999). If a production process is technically inefficient, it is possible to produce more output with the same inputs or the same output with fewer inputs by

enhancing the technology or the way inputs are utilised. In economics, to figure out the impact of exogenous determinants on production, the technical efficiency score is converted to technical inefficiency by subtracting the technical efficiency score from 1 (Farrel, 1957; Coelli et al., 2005; Vázquez-Rowe & Tyedmers, 2013; Zhang et al., 2017). Thus, how the factors affecting inefficiency would be investigated.

To sum off, efficiency is the theory, technical efficiency measures the ability of a producer to obtain the maximum output from a given quantity of inputs. For reasonable sorting out the determinants of inefficiency, technical inefficiency is calculated by 1 minus technical efficiency (or the inverse of technical efficiency).

1.5 Problem Statement

The China government has set an objective of enhancing agricultural self-sufficiency and reducing reliance on imports, particularly given the unstable global environment, with efforts to increase the self-sufficiency rate (SSR) to 100%. Additionally, China's agricultural Five-Year Plans have evolved from solely focusing on increasing output to emphasizing both increased production and improved efficiency, advocating for maintaining inputs while boosting output. In line with this overarching goal, the Shaanxi Five-Year Development Plan has advocated for the adoption of a sustainable development approach, emphasizing increased production and enhanced agriculture efficiency. Despite a gradual rise in the agricultural output in Shaanxi, the inefficiency problems seem to exist.

In the case of crop farming subsector, Shaanxi's grain output per unit area lag the national average, ranking 30th, out of 31 provinces in mainland China. Additionally, per capita vegetable consumption in Shaanxi is 15.09% below the national average. These figures indicate inefficiencies in the crop farming practice.

Similarly, the performance of the livestock subsector in Shaanxi falls below the national average. This is evident through declining livestock output and diminishing growth rates across various animal categories. In the fishery subsector, Shaanxi also grapples with inefficiencies, with its output per unit area being merely half of the national average. Moreover, Shaanxi's fishery output ranks 26th among mainland Chinese provinces.

Across all subsectors of Shaanxi's agriculture, performance lags behind the national average. Enhancing the efficiency of Shaanxi's agriculture holds the potential to contribute significantly to the government's objectives of sustainability and self-sufficiency in the agriculture sector. Hence, a comprehensive study focused on evaluating Shaanxi's agriculture efficiency is warranted. Such an investigation can shed light on areas requiring improvement and contribute to the realization of the government's agricultural goals.

1.6 Research Questions

Building upon the issues discussed in the preceding section, it becomes evident that Shaanxi's agriculture sector seems to suffer from inefficiency. Consequently, a fundamental query arises: What is the efficiency performance of Shaanxi's agriculture sector? To address this inquiry, this study attempts to delve into three specific agriculture subsectors. The specific questions are as below:

(a) What is the efficiency performance of Shaanxi crop farming subsector?

(b) What are the factors affect Shaanxi crop farming subsector?

(c) What is the efficiency performance of Shaanxi livestock subsector?

(d) What are the factors affect Shaanxi livestock subsector?

(e) What is the efficiency performance of Shaanxi aquaculture industry?

(f) What are the factors affect inefficiency in Shaanxi aquaculture industry?

1.7 Research Objectives

The general objective of this study is to examine the efficiency performance of the agriculture sector in Shaanxi Province. The specific objectives are:

i. to estimate the efficiency of Shaanxi's crop farming subsector and to investigate the factors that affect inefficiency.

ii. to estimate the efficiency of Shaanxi's livestock subsector and to investigate the factors that affect inefficiency.

iii. to estimate the efficiency of Shaanxi's fishery subsector and to investigate the factors that affect inefficiency.

1.8 Significance of the Study

While empirical studies have examined the technical efficiency of various agriculture sectors within China, there is a noticeable gap in research specifically focused on evaluating the technical efficiency of crop farming, livestock, and fishery subsectors in Shaanxi province. There is a limited exploration into the technical efficiency of using individual agricultural products as Decision Making Units (DMUs) within each agriculture subsector.

In the crop farming subsector, the study includes a comparison of technical efficiency among different vegetable varieties, glasshouse cultivation, and open-field cultivation. These results can help revise the Shaanxi agricultural department's development plan, which advocates for increasing the number of greenhouses. In the livestock subsector, this study is the first to analyze the technical efficiency of