A Linear Programming Approach for Finding Efficient Allocation of Resource In Jilin, China

by

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Abstract

China has always been one of the world's largest grain producers, and Jilin is the largest grain-producing province in China. According to the Report on the Work of the Government 2018, the yield per mu (0.165 acre) has remained the first of the country for the past five years; and the grain commodity rate, the volume of transfers and the possession per capita have remained at the forefront of the country, making a significant contribution to ensuring national food security. This study is to compare efficient allocation of resources through designing a linear programming model with current allocation of resources to find out potential improvements and policy suggestions for future agricultural structure, rational cultivation of grains and market prediction for Jilin, China. In addition, this study examines what role the government regulations play in the grain production in China and how the trade war affects the grain production.

Keyword: *Optimization, Linear Programming, Government Regulations, Trade War*

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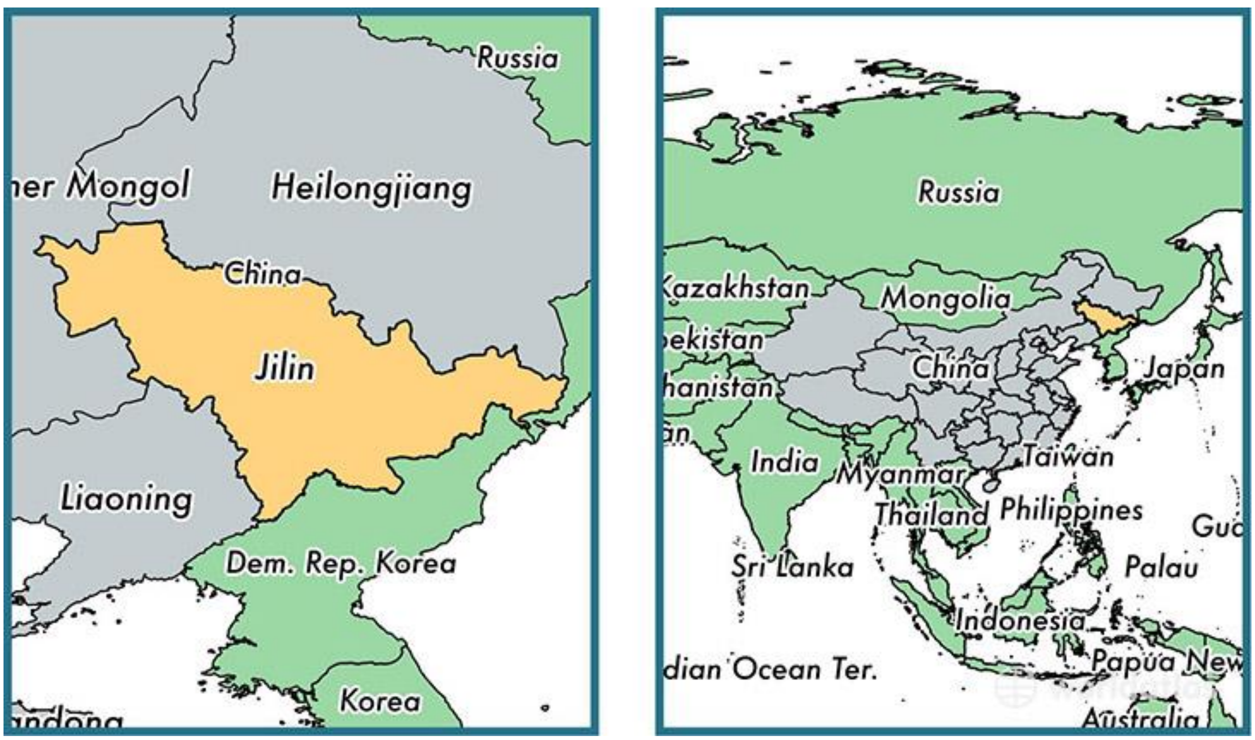
1. INTRODUCTION

1.1. History of Jilin, China

Jilin is one of the provinces of China. It is adjacent to Heilongjiang Province to the North and to Liaoning Province to the Southwest. Russia and North Korea are on the Southeast of Jilin Province (Nelson 2002). The climate of Jilin Province is temperate continental monsoon and on the eastern parts, the climate is relatively mild and humid. Jilin is multiethnic, Chinese, Koreans, Mongolians and Manchurians are the majority. Close to one fifth of the eastern part of Jilin Province is Yanbian Korean Autonomous Prefecture. In addition, there exist some Mongolian as well as Manchurian autonomous counties.

Figure 1: Location of Jilin, China



Source: https://www.worldatlas.com/as/cn/22/a-jilin-province-china.html

Jilin is among the forested areas in China. About 40% of the entire province is covered with forest. The eastern region which is occupied with mountains has plenty of organic medicine including ginseng. The eastern part has abundant water resources. Yalu and Tumen River mark the border with North Korea. The central and western parts of Jilin Province lack water resources and are mainly arid in nature. The province has the largest oil reserves in China, which is about 15 percent of the country's oil shale reserve (Nelson 2002).

The railways infrastructure is highly developed. The region is home to Jingha, Hada and Jihui Railways. They are used to facilitate transportation of various products to and from the region. The other developed means of transport is expressways. Expressways play a greater role in the transportation of people and products (Nelson 2002). Other forms of infrastructure that facilitate transportation include ships, airports, and subways.

Jilin is land locked and therefore has no access to any water body. River navigation takes place between the months of April to November. River ports are found at Da'an, the city of Jilin and Fuyu. In the year 2007, the construction of two-phase RMB60 was commenced and later on finished successfully. A well-established port is on Songhua River with an annual throughput of about two million tons. Aviation takes Changchun as the center aided with countries such as Japan.

Jilin is well endowed with numerous tourist sites that attract tourists across the world. Jilin has Koguryo Sites and tombs. Paektu Mountain as well as Heaven Lake which are found on the border with North Korea is among the busiest tourist destinations because of their natural scenery.

Jilin has faced the problem of high energy consumption due to rapid economic growth after a successful completion of economic reforms. The policy of revitalization of the old industrial base brought about reindustrialization. The challenges faced by Jilin Province are similar to old industrial regions in the west including Ruhr in Germany. The challenges include exhaustions of the resources, slowed growth in the economy and single-industry structure (Earnshaw 2005).

It is evident that Jilin is one of the most productive provinces in China. With a well-established transportation network and a major tourist attraction center, the province contributes greatly towards the country's economy. It is essential that resources are efficiently allocated to improve the economy and create employment opportunities.

1.2. Objective of this Study

This study is to compare efficient allocation of resources through designing a linear programming model with the current allocation of resources in Jilin, China to find out the most efficient allocation. As we know linear programming can be used to provide a scientific basis and make an optimal decision for the use of limited human, material, financial and other resources, but we also need to consider two stages (production and trading) in the grain market often accompanied by deterministic and uncertain factors. This study uses a linear programming model to examine what role the government regulations play in the grain production in China and how the trade war affects the grain production. The results and policy implications of this study can be useful for improving future agricultural structure, rational cultivation of grains, and market prediction for Jilin, China.

Specifically, this study will address three effects, weather effects, government effects, and trade war effects of resource allocation in the grain industries in China.

2. LITERATURE REVIEW

This chapter discusses linear programming, government regulations, and trade war. Linear programming can be used to provide a scientific basis and make an optimal decision for the use of limited human, material, financial and other resources. Government policies including monetary policy may change the price and cost in various markets and, in turn, change the allocation of resources. Trade war refer to a series of retaliations and counter-retaliations caused by high tariff and non-tariff trade barriers, which can restrict the entry of goods from other countries into the domestic market and affect resource allocations.

2.1. Linear Programming

Linear programming is a mathematical technique that is used in computer modeling (Vanderbei 2007). It is used to find the most viable solution in the allocation of limited resources so as to be able to attain maximum earnings. Nevertheless, the technique is only applicable where all relationships are linear and can contain a limited cost function class (Lewis 2008).

Linear programming, in most cases, is used to maximize revenue or minimize cost. According to Matousek and Gartner (2007), the initial step in finding a solution in a linear programming problem entails setting up a function that corresponds to the cost and revenue. It can also represent some other quantity that can be maximized or minimized in relation to the constraints of the subject in question. The constraints can then be defined with a system of linear inequalities (Ping 2014).

The systems of inequalities have a solution known as feasible region (Mokhtar et al 2004). Inequalities are plotted in a graph to establish the coordinates of the vertices of that particular region. After that, the function of each vertex is evaluated. From the evaluation, the largest value represents the maximum value of the function while the smallest value represents the smallest value (Bachem & Kern 2012; Sallan et al 2015).

Linear programming can be applicable to a number of fields of study. It can be applied in mathematics, business, economics and engineering. Transportation, telecommunication, energy and manufacturing are some of the industries that make use of linear programming (Darst 1990). Linear programming is important because through it, business problems can be easily solved. Problems under different limitations and conditions can be easily solved; therefore, managers find it easy to work under favorable conditions (Papadimitriou & Steiglitz 1988; Hillier & Leberman 1986).

2.2. Government Regulations

Monetary policy is one of the ways through which the government, through the central bank controls the supply of money in an economy by ensuring that it is in line with the growth and price objectives determined by the government (Hall 2018). The government ensures that it is the only entity that legally establishes their respective currencies (George 2011). As soon as they can get away with that, government would want to inflate the currencies because this provides a medium-term economic support as firms charge more for their products. Furthermore, it minimizes the government bonds' value issued in the currency that is inflated and owned by investors (NC Soybean Producers Association 2018).

In order to maintain the surplus supply of low-priced food for urban residents, the government can intervene by imposing price controls and rationing grain sales. Further, a government can also use procurement quotas below the prices in the market especially in areas most affected by inflation (Joskow & Rose 2000). In China, the government required grain stations to sell grain stocks of the state at ceiling prices. It also restricted grain movement out of surplus places to overwhelm local prices (OECD 2005; Rozelle et al 2000).

Sometimes, the government forbids exports of grains in such instances (Westcott & Hoffman 2000). For instance, in India, production problems forced the government to ban rice exports (Wright 2009). Lastly, governments frequently help farmers through setting price floors in the markets for agricultural products. By using a price floor, governments forbid prices below the minimum level (Chand 2003; Arnott 2018).

2.3. Trade War

Trade wars refer to a series of retaliations and counter-retaliations caused by high tariff and non-tariff barriers, restricting the entry of goods from other countries into the domestic market, and competing for foreign markets through dumping and currency depreciation at the same time (Rowe 1994; Baumol & Blinder 1985). However, if trade wars are limited to mutual impositions of high tariff rates, they are called tariff wars (Findlay et al 2007).

Recently, President Donald Trump and his Chinese counterpart Xi Jinping have openly targeted each other's trade and it is proving to be a real skirmish. According to Warner (2018), the threat of the long-time trade war between the two countries is in danger of breaking up. There are a number of impacts that are associated such kinds of trade wars (Applebaum 2016).

The effects of trade war will be felt in different fronts including currencies, commodities as well as companies. Stock market will be gravely affected by the trade war between the two countries (Warner 2018). The US companies that are known to provide material and goods to China will be adversely affected (Melitz 2003). Some sectors such as soybeans, pork, milk, aerospace and defense will be vulnerable to trade war. China is the largest destination of U.S. soybean exports. China's high tariffs on imports from the U.S. cause significant damages to U.S. soybean farmers while benefit other soybean exporters such as Brazil. The trade war also brings large negative effects on U.S. pork and milk industry. Boeing is a top exporter of the U.S. and is already feeling the potential impact of trade war. China looks at the possibility of going for rivals like Airbus in case it is forced to. Mobile phones and computer equipment are exposed to retaliation from China. The trade war also affected the relative values of major currencies including U.S. dollar, European euro, Japanese yen, and Chinese yuan. All these changes due to the trade war between the United States and China can greatly affect the resource allocation in the grain industries in Jilin, China.

Therefore, it is important that the leaders look beyond their differences and think about the likely scenarios. Cooperation among the countries is of great benefit not just to these countries but to other countries as well (Yueh 2018; Conybeare 1987).

3. LINEAR PROGRAMMING MODEL

3.1. Problem Definition

Jilin is located in the northeastern part of China. It is known as a major grain producing and agricultural province. According to the Report on the Government Work of 2018, the current cultivated land in Jilin is 86.98 million hectares in total and 3.16 hectares per capita, which is 2.18 times of the national average, ranking the 5^{th} in China. Jilin is known for four major staple food crop production: soybean, corn, rice and peanut, based on the climatic characteristics of the northern region. All these four productions are one crop per year. In general, farming time in Jilin is from April to November, sowing in April and reaping in November for soybean; sowing in April and reaping in October for corn; sowing in May and reaping in October for rice; sowing in April and reaping in October for peanut.

Along with the development of the agricultural economy and the improvement of rural consumption levels, the cost of living in rural area has also increased. The government always actively supports and encourages households for entrepreneurial innovation to add endogenous motivation to modern agricultural development. Therefore, the government provides low-interest loans to households in the amount of ￥979 millions (Chinese Yuan) at an annual interest rate of 4.35%. In order to have an efficient and balanced use of soil nutrients, prevent diseases, insects and grass damage, and improve the physical and chemical properties of the soil and regulates soil fertility, households will plan a crop rotation by choosing two crops from any of the four crops.

Figure 2 presents the current allocation of resources in Jilin, China. Households allocate 11 million hectares for soybean, 59 million hectares for corn, 13 million hectares for rice, 22 million hectares for peanut, which can make a maximum revenue at ￥31,404.13 million. Households need to work 241 days, 55 days for soybean, 59 days for corn, 39 days for rice, 88 days for peanut. ￥8,549 million need to be borrowed, which causes a huge economic pressure for the government.

Table 1: Current Allocation of Resources in Jilin, China

	Soybean	Corn	Rice	Peanut	Borrow	
Current Value	11	59	13	22	979	Revenue
Gross Revenue	233.4	301.42	413.3	260.12	(4.35%)	31,404.13
Land	11	59	13	22	0	
Labor	55	59	39	88	0	

Table 2: Income Comparison in Jilin and Nationwide

	Jilin	Percentage	China	Percentage
Income	11,326.2		11,421.7	
Wage	2,097.4	18.52%	4,600	40.28%
Net Operating	7,878.1	69.56%	4,503.6	39.4%
Transfer	1,152.1	10.17%	2,066.3	18.09%
Net Income	198.6	1.75%	251.5	2.2%

Sources: Ministry of Agriculture and Rural Affairs of the People's Republic of China

According to the comparison of the disposable income and the source composition with the national average, which seems that the current disposable income in Jilin is relatively low, and the income source is mainly based on the management income of farming. I design a linear programming model to find efficient allocations of resources, and the results and policy implications of this study can be useful for improving future agricultural structure, rational cultivation of grains, and market prediction for Jilin, China. I consider six crop rotation plans in this thesis.

1. The households only plant soybean and corn, farming time is from April to November.
2. The households only plant soybean and rice, farming time is from April to November.
3. The households only plant soybean and peanut, farming time is from April to November.
4. The households only plant corn and rice, farming time is from April to October.
5. The households only plant corn and peanut, farming time is from April to November.
6. The households only plant rice and peanut, farming time is from April to October.

3.2. Model Designer

The detailed principle for solving crop rotation plans will be addressed in this section. Before designing a linear programming model, I first discuss the notations, data and linear programming model sample in the following.

3.2.1. Notations

3.2.1.1 Soybean – Corn

X_1 the amount hectare of soybean planted

X_2 the amount hectare of corn planted

A_1 the gross revenue of soybean planted per acre

A_2 the gross revenue of corn planted per acre

A_5 at an annual interest rate of 4.35%

B_1 the total variable cost of soybean planted

B_2 the total variable cost of corn planted

C_1 the days of soybean planted per acre

C_2 the days of corn planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the household's income

T the total days households planted

T_1 the total days soybean planted

T_2 the total days corn planted

3.2.1.2 Soybean – Rice

X_1 the amount hectare of soybean planted

X_3 the amount hectare of rice planted

A_1 the gross revenue of soybean planted per acre

A_3 the gross revenue of rice planted per acre

A_5 at an annual interest rate of 4.35%

B_1 the total variable cost of soybean planted

B_3 the total variable cost of rice planted

C_1 the days of soybean planted per acre

C_3 the days of rice planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the household's income

T the total days households planted

T_1 the total days soybean planted

T_3 the total days rice planted

3.2.1.3 Soybean – Peanut

X_1 the amount hectare of soybean planted

X_4 the amount hectare of peanut planted

A_1 the gross revenue of soybean planted per acre

A_4 the gross revenue of peanut planted per acre

A_5 at an annual interest rate of 4.35%

B_1 the total variable cost of soybean planted

B_4 the total variable cost of peanut planted

C_1 the days of soybean planted per acre

C_4 the days of peanut planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the household's income

T the total days households planted

T_1 the total days soybean planted

T_4 the total days peanut planted

3.2.1.4 Corn – Peanut

X_2 the amount hectare of corn planted

X_4 the amount hectare of peanut planted

A_2 the gross revenue of corn planted per acre

A_4 the gross revenue of peanut planted per acre

A_5 at an annual interest rate of 4.35%

B_2 the total variable cost of corn planted

B_4 the total variable cost of peanut planted

C_2 the days of corn planted per acre

C_4 the days of peanut planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the household's income

T the total days households planted

T_2 the total days corn planted

T_4 the total days peanut planted

3.2.1.5 Corn – Rice

X_2 the amount hectare of corn planted

X_3 the amount hectare of rice planted

A_2 the gross revenue of corn planted per acre

A_3 the gross revenue of rice planted per acre

A_5 at an annual interest rate of 4.35%

B_2 the total variable cost of corn planted

B_3 the total variable cost of rice planted

C_2 the days of corn planted per acre

C_3 the days of rice planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the households income

T the total days households planted

T_2 the total days corn planted

T_3 the total days rice planted

3.2.1.6 Rice – Peanut

X_3 the amount hectare of rice planted

X_4 the amount hectare of peanut planted

A_3 the gross revenue of rice planted per acre

A_4 the gross revenue of peanut planted per acre

A_5 at an annual interest rate of 4.35%

B_3 the total variable cost of rice planted

B_4 the total variable cost of peanut planted

C_3 the days of rice planted per acre

C_4 the days of peanut planted per acre

L the total amount area planted

B the amount households are willing to borrow

B_A the amount households can borrow

I the household's income

T the total days households planted

T_3 the total days rice planted

T_4 the total days peanut planted

3.2.2. Linear Programming Model Sample

Maximize $Z = A_iX_j + A_jX_i - A_5B$ (i=1,2,3,4; j=1,2,3,4)

Subject to

$X_i + X_j \leqslant L$ **Land Constraint**

$B_iXj + B_iX_j - B \leqslant I$

$B \geqslant B_A$ **Capital Constraint**

$C_iXj \leqslant T_i$ **Labor Constraint**

3.2.3. Data

On one hand, I pay more attention on the four major crops themselves, soybean, corn, rice and peanut based on the Report on the Jilin Government Work of 2018. Table 1 provides an overview of basic information for the four major crops, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥844.1 for soybean, ￥980.33 for corn, ￥1,703.1 for rice, ￥1,096.8 for peanut; the gross revenue is ￥233.4 for soybean, ￥301.42 for corn, ￥413.3 for rice, and ￥260.12 for peanut.

Table 3: Grains Gross Revenue Computation I

	SOYBEAN	CORN	RICE	PEANUT
VALUE PER HECTARE	675.3	980.33	1703.1	1096.8
SUBSIDIES PER HECTARE	168.8	--------	--------	--------
EXPECTED REVENUE	844.1	980.33	1703.1	1096.8
FERTILIZER	63.8	183.28	131.6	130.22
PESTICIDE	22.9	18.57	24.9	32.4
SEED	32.9	56.21	34.0	110.2
MACHINERY RENT	93.9	89.54	158.0	118
LABOR COST	257.2	331.31	445.2	61.86
LANDING RENT	140	--------	496.1	384
TOTAL VARIABLE COST	610.7	678.91	1289.8	836.68
GROSS REVENUE	233.4	301.42	413.3	260.12

Source: Report on the Work of the Jilin Government 2018.

On the other hand, I turn my attention to the labor seasonality. I need to find out when to sow and when to reap as much as possible, and what the maximum cultivation is. Table 4 provides an overview of the specific conditions for these crops, which includes the sowing time, reaping time, total working days and working days per acre for households, and the maximum land planted for the major four crops. Households have to work from April to November, the longest working time is 243 days from April to November for soybeans.

Table 4: Crops Sowing and Reaping Computation

	SOYBEAN	**CORN**	**RICE**	**PEANUT**
SOWING BEGINS	April	April	May	April
REAPING ENDS	November	October	October	October
WORKING DAYS	243	213	183	213
WORKING DAYS PER ACRE	22	3.6	14	9.6
MAXIMUM LAND	11	59	13	22

Source: Report on the Work of Jilin Government 2018.

3.3. Analysis

According to the data and linear programming model, the optimization of each crop rotation plan will be addressed in this section. Then I find a crop rotation plan that is more relevant to the actual situation.

3.3.1. Soybean – Corn

Table 5 provides an overview of basic information for soybean and corn, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥844.1 for soybean, ￥980.33 for corn; the gross revenue is ￥233.4 for soybean, ￥301.42 for corn.

Table 5: Soybean - Corn Computation

	SOYBEAN	CORN
VALUE PER HECTARE	675.3	980.33
SUBSIDIES PER HECTARE	168.8	--------
EXPECTED REVENUE	844.1	980.33
FERTILIZER	63.8	183.28
PESTICIDE	22.9	18.57
SEED	32.9	56.21
MACHINERY RENT	93.9	89.54
LABOR COST	257.2	331.31
LANDING RENT	140	--------
TOTAL VARIABLE COST	610.7	678.91
GROSS REVENUE	233.4	301.42

Source: Report on the Work of the Jilin Government 2018.

3.3.1.1 Linear Programming Model

Maximize $Z = 233.4X_1 + 301.42X_2 - 4.35\%B$

Subject to

$$\begin{cases} X_1 + X_2 \leqslant L \\ 610.7X_1 + 678.91X_2 - B \leqslant 86{,}079 \\ B \geqslant 979 \\ 22X_1 \leqslant 243 \\ 3.6X_1 \leqslant 213 \end{cases}$$

3.3.1.2 Result

Table 6 presents the efficient allocation of soybean and corn in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 59.17 hectares (in millions) for corn, which can make a maximum revenue at ￥20,369.44 (in millions). Households need to work 243days for soybean and corn.

Table 6: Efficient Allocation of Soybean and Corn in Jilin, China

	Soybean	Corn	Borrow			
Opt Value	11.05	59.17	979	Revenue		
Gross Revenue	233.4	301.42	(4.35%)	20,369.44		
Constraint				LHS	Relationship	RHS
Land	1	1	0	70.21	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Corn	0	3.6	0	213	<=	213
Capital	610.70	679	-1	45,935.3	<=	86,079
Loan	0	0	1	979	>=	979

3.3.2. Soybean – Rice

Table 7 provides an overview of basic information for soybean and rice, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥844.1 for soybean, ￥1,703.1 for rice; the gross revenue is ￥233.4 for soybean, and ￥413.3 for rice.

Table 7: Soybean - Rice Computation

	SOYBEAN	RICE
VALUE PER HECTARE	675.3	1703.1
SUBSIDIES PER HECTARE	168.8	--------
EXPECTED REVENUE	844.1	1703.1
FERTILIZER	63.8	131.6
PESTICIDE	22.9	24.9
SEED	32.9	34.0
MACHINERY RENT	93.9	158.0
LABOR COST	257.2	445.2
LANDING RENT	140	496.1
TOTAL VARIABLE COST	610.7	1289.8
GROSS REVENUE	233.4	413.3

Source: Report on the Work of the Jilin Government 2018.

3.3.1.3 Linear Programming Model

Maximize $Z = 233.4X_1 + 413.3X_3 – 4.35\%B$

Subject to
$$\begin{cases} X_1 + X_3 \leqslant L \\ 610.7X_1 + 1{,}289.8X_3 - B \leqslant 86{,}079 \\ B \geqslant 979 \\ 22X_1 \leqslant 243 \\ 14X_3 \leqslant 183 \end{cases}$$

3.3.1.4 Result

Table 8 presents the efficient allocation of soybean and rice in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥7,937.844 (in millions). Households need to work 243 days for soybean and rice.

Table 8: Efficient Allocation of Soybean and Rice in Jilin, China

	Soybean	Rice	Borrow			
Opt Value	11.05	13.07	979	Revenue		
Gross Revenue	233.4	413.3	(4.35%)	7,937.844		
Constraint				LHS	Relationship	RHS
Land	1	1	0	24.12	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Rice	0	14	0	183	<=	183
Capital	610.70	1,289.8	-1	22,625.99	<=	86,079
Loan	0	0	1	979	>=	979

3.3.3. Soybean – Peanut

Table 9 provides an overview of basic information for soybean and peanut, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is 844.1 for soybean, 1096.8 for peanut; the gross revenue is 233.4 for soybean, 260.12 for peanut.

Table 9: Soybean - Peanut Computation

	SOYBEAN	PEANUT
VALUE PER HECTARE	675.3	1096.8
SUBSIDIES PER HECTARE	168.8	--------
EXPECTED REVENUE	844.1	1096.8
FERTILIZER	63.8	130.22
PESTICIDE	22.9	32.4
SEED	32.9	110.2
MACHINERY RENT	93.9	118
LABOR COST	257.2	61.86
LANDING RENT	140	384
TOTAL VARIABLE COST	610.7	836.68
GROSS REVENUE	233.4	260.12

Source: Report on the Work of the Jilin Government 2018.

3.3.1.5 Linear Programming Model

Maximize $Z = 233.4X_1 + 260.12X_4 – 4.35\%B$

Subject to

$$\begin{cases} X_1 + X_4 \leqslant 105 \\ 610.7X_1 + 836.68X_4 - B \leqslant 86{,}079 \\ B \geqslant 979 \\ 22X_1 \leqslant 243 \\ 9.6X_4 \leqslant 213 \end{cases}$$

3.3.1.6 Result

Table 10 presents the efficient allocation of soybean and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥8,306.835 (in millions). Households need to work 243 days for soybean and peanut.

Table 10: Efficient Allocation of Soybean and Peanut in Jilin, China

	Soybean	Peanut	Borrow			
Opt Value	11.05	22.19	979	Revenue		
Gross Revenue	233.4	260.12	(4.35%)	8,306.835		
Constraint				LHS	Relationship	RHS
Land	1	1	0	33.23	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Rice	0	9.6	0	213	<=	213
Capital	610.70	836.7	-1	24,330.3	<=	86,079
Loan	0	0	1	979	>=	979

3.3.4. Corn – Rice

Table 11 provides an overview of basic information for corn and rice, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥980.33 for corn, ￥1703.1 for rice; the gross revenue is ￥301.42 for corn, and ￥413.3 for rice.

Table 11: Corn - Rice Computation

	CORN	RICE
VALUE PER HECTARE	980.33	1703.1
SUBSIDIES PER HECTARE	--------	--------
EXPECTED REVENUE	980.33	1703.1
FERTILIZER	183.28	131.6
PESTICIDE	18.57	24.9
SEED	56.21	34.0
MACHINERY RENT	89.54	158.0
LABOR COST	331.31	445.2
LANDING RENT	--------	496.1
TOTAL VARIABLE COST	678.91	1289.8
GROSS REVENUE	301.42	413.3

Source: Report on the Work of the Jilin Government 2018.

3.3.1.7 Linear Programming Model

Maximize $Z = 301.42X_1 + 413.3X_4 – 4.35\%B$

Subject to

$$\begin{cases} X_2 + X_3 \leqslant 105 \\ 678.91X_2 + 1{,}289.8X_3 - B \leqslant 86{,}079 \\ B \geqslant 979 \\ 3.6X_2 \leqslant 213 \\ 14X_3 \leqslant 183 \end{cases}$$

3.3.1.8 Result

Table 12 presents the efficient allocation of corn and rice in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥23,193.85 (in millions). Households need to work 213days for corn and rice.

Table 12: Efficient Allocation of Corn and Rice in Jilin, China

	Corn	Rice	Borrow			
Opt Value	59.17	13.07	979	Revenue		
Gross Revenue	301.42	413.3	(4.35%)	23,193.85		
Constraint				LHS	Relationship	RHS
Land	1	1	0	61.31	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Rice	0	14	0	30	<=	183
Capital	678.91	1,289.8	-1	56,049.37	<=	86,079
Loan	0	0	1	979	>=	979

3.3.5. Corn – Peanut

Table 13 provides an overview of basic information for corn and peanut, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥980.33 for corn, ￥1,096.8 for peanut; the gross revenue is ￥301.42 for corn, and ￥260.12 for peanut.

Table 13: Corn - Peanut Computation

	CORN	PEANUT
VALUE PER HECTARE	980.33	1096.8
SUBSIDIES PER HECTARE	--------	--------
EXPECTED REVENUE	980.33	1096.8
VARIABLE COST		
FERTILIZER	183.28	130.22
PESTICIDE	18.57	32.4
SEED	56.21	110.2
MACHINERY RENT	89.54	118
LABOR COST	331.31	61.86
LANDING RENT	--------	384
TOTAL VARIABLE COST	678.91	836.68
GROSS REVENUE	301.42	260.12

Source: Report on the Work of the Jilin Government 2018.

3.3.1.9 Linear Programming Model

Maximize $Z = 301.42X_2 + 260.12X_4 - 4.35\%B$

Subject to

$$X_2 + X_4 \leqslant 105$$

$$678.91X_2 + 836.68X_4 - B \leqslant 86{,}079$$

$$B \geqslant 979$$

$$3.6X_2 \leqslant 213$$

$$9.6X_4 \leqslant 213$$

3.3.1.10 Result

Table 14 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥23,562,84 (in millions). Households need to work 213days for corn and peanut.

Table 14 Efficient Allocation of Corn and Peanut in Jilin, China

	Corn	Peanut	Borrow			
Opt Value	59.17	22.19	979	Revenue		
Gross Revenue	301.42	260.12	(4.35%)	23,562,84		
Constraint				LHS	Relationship	RHS
Land	1	1	0	81.35	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Rice	0	9.6	0	30	<=	213
Capital	678.91	836.7	-1	57,753.68	<=	86,079
Loan	0	0	1	979	>=	979

3.3.6. Rice – Peanut

Table 15 provides an overview of basic information for rice and peanut, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥1,703.1 for rice, ￥1,096.8 for peanut; the gross revenue is ￥413.3 for rice, and ￥260.12 for peanut.

Table 15: Rice - Peanut Computation

	RICE	PEANUT
VALUE PER HECTARE	1703.1	1096.8
SUBSIDIES PER HECTARE	--------	--------
EXPECTED REVENUE	1703.1	1096.8
VARIABLE COST		
FERTILIZER	131.6	130.22
PESTICIDE	24.9	32.4
SEED	34.0	110.2
MACHINERY RENT	158.0	118
LABOR COST	445.2	61.86
LANDING RENT	496.1	384
TOTAL VARIABLE COST	1289.8	836.68
GROSS REVENUE	413.3	260.12

Source: Report on the Work of the Jilin Government 2018.

3.3.1.11 Linear Programming Model

Maximize $Z = 413.3X_3 + 260.12X_4 - 4.35\%B$

Subject to

$$\begin{cases} X_3 + X_4 \leqslant 105 \\ 1{,}289.8X_2 + 836.68X_4 - B \leqslant 86{,}079 \\ B \geqslant 979 \\ 14X_3 \leqslant 183 \\ 9.6X_4 \leqslant 213 \end{cases}$$

3.3.1.12 Result

Table 16 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 13.07 hectares (in millions) for rice, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥11,131.25 (in millions). Households need to work 213days for rice and peanut.

Table 16: Efficient Allocation of Rice and Peanut in Jilin, China

	Corn	Peanut	Borrow			
Opt Value	13.07	22.19	979	Revenue		
Gross Revenue	413.3	260.12	(4.35%)	11,131,25		
Constraint				LHS	Relationship	RHS
Land	1	1	0	35.26	<=	105
Lab Corn	14	0	0	183	<=	183
Lab Rice	0	9.6	0	213	<=	213
Capital	1,289.8	836.7	-1	34,444.37	<=	86,079
Loan	0	0	1	979	>=	979

4. RESULTS

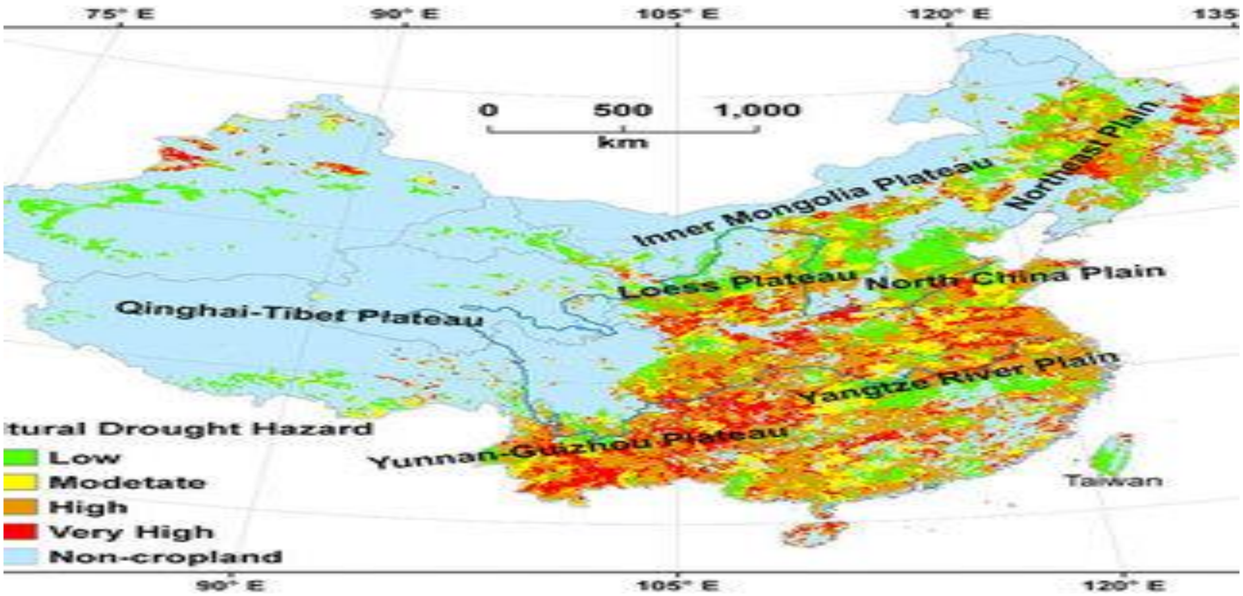
The analysis using the linear programming model with the data set provides the efficient resource allocations and shows sowing and reaping corn and peanut can make a maximum revenue. however, the reality always shows a large difference from the optimization. In this section, I conduct an analysis to show how dependent variable is affected by independent variables, especially weather, government policy and trade war. In addition, the comparison between the linear programming approach and analytical approach results are shown in this section.

4.1. Linear Programming Results with Weather Effects

The weather and climate change can significantly affect the world's major food productions. As temperature increases, crop growth period in the high latitudes will be extended and the output will increase accordingly. Increase of the high temperature and drought at low latitudes will intensify the desertification of the land. They will also cause agricultural pests to multiply, and increase the damage to crops. The crop outputs in the middle and low latitudes will decline. The world's major crops producing regions are widely distributed, and the arable land in high latitudes is limited. Therefore, the increased crops output in high latitudes due to climate change is far from compensating for the reduction of crops production in the middle- and low-latitude regions.

As the sea level rises, the seawater will invert back into the inland, and the saline soil will expand inland, which will make the salinization and swamping of crop growing areas more serious. The planting fields near the coastal areas will decrease and the crops output will decrease. Figure 2 presents the drought distribution in China, there is low drought hazard in the western and eastern area, but high drought hazard in the middle.

Figure 2: Drought Distribution in China



Source: ResearchGate

Figure 3: Weather by Month, Jilin

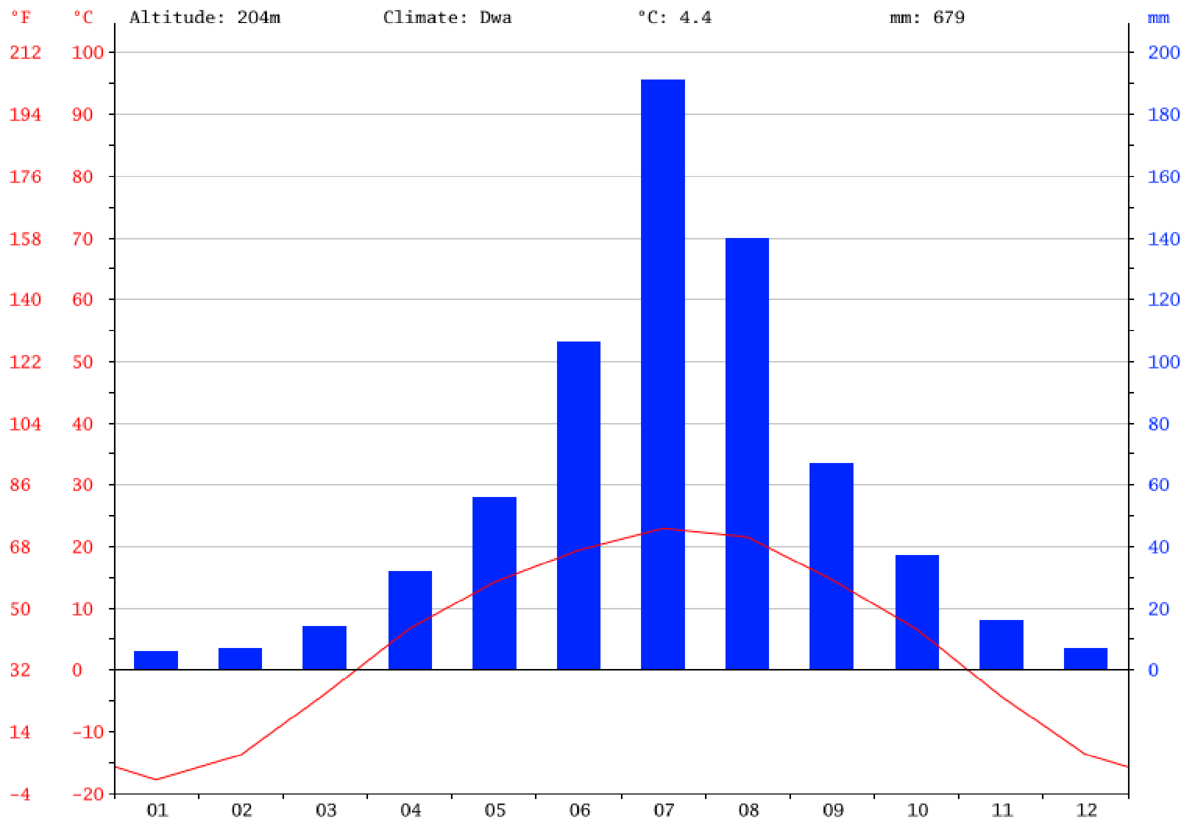


Figure 3 presents the weather by month in Jilin, most precipitation falls in July, with an average of 191 mm. Also July is the warmest month of the year, with an average of 22.9'C. Households are sowing and reaping from April to November, but April and November are colder with an average of 15'C and 8'C, respectively, and July and August have most precipitations falls with an average of 191mm and 141mm, respectively, which will reduce the crop yields and increase the cost. According to the current market situation, peanut has a small transaction volume in Jilin, but soybean and corn have large but decreasing transaction volumes. Rice has a large and increasing transaction volume in Jilin.

Table 17 provides an overview of basic information for the four major crops, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥806.6 for soybean, ￥973.46 for corn, ￥1,812.6 for rice, ￥1,096.8 for peanut; the gross revenue is ￥48.3 for soybean, ￥244.54 for corn, ￥473.6 for rice, and ￥260.12 for peanut.

Table 17: Grains Gross Revenue Computation II

	SOYBEAN	CORN	RICE	PEANUT
VALUE PER HECTARE	644.9	973.46	1812.6	1096.8
SUBSIDIES PER HECTARE	161.7	--------	--------	--------
EXPECTED REVENUE	806.6	973.46	1812.6	1096.8
FERTILIZER	63.8	174.6	131.6	130.22
PESTICIDE	22.9	17.32	24.9	32.4
SEED	32.9	47.63	34.0	110.2
MACHINERY RENT	86.9	121.46	150.1	118
LABOR COST	268.8	172.72	498.4	61.86
LANDING RENT	283	195.19	500	384
TOTAL VARIABLE COST	758.3	728.92	1339	836.68
GROSS REVENUE	48.3	244.54	473.6	260.12

Sources: Various Jilin Government Report Computation

4.1.1. Optimization

Table 18 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 59.17 hectares (in millions) for corn, which can make a maximum revenue at ￥14,959.53 (in millions). Households need to work 243days for soybean and corn.

Table 18: Efficient Allocation of Soybean and Corn in Jilin, China (WE)

	Soybean	Corn	Borrow			
Opt Value	11.05	59.17	979	Revenue		
Gross Revenue	48.3	244.54	(4.35%)	14,959.53		
Constraint				LHS	Relationship	RHS
Land	1	1	0	70.21	<=	85
Lab Soybean	22	0	0	243	<=	243
Lab Corn	0	3.6	0	213	<=	213
Capital	758.8	729	-1	50,524.53	<=	86,079
Loan	0	0	1	979	>=	979

Table 19 presents the efficient allocation of soybean and rice in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥6,681.538 (in millions). Households need to work 243 days for soybean and rice.

Table 19: Efficient Allocation of Soybean and Rice in Jilin, China (WE)

	Soybean	Rice	Borrow			
Opt Value	11.05	13.07	979	Revenue		
Gross Revenue	233.4	413.3	(4.35%)	6,681.538		
Constraint				LHS	Relationship	RHS
Land	1	1	0	24.12	<=	85
Lab Soybean	22	0	0	243	<=	243
Lab Rice	0	14	0	183	<=	183
Capital	758.30	1,339.0	-1	24,899.41	<=	86,079
Loan	0	0	1	979	>=	979

Table 20 presents the efficient allocation of soybean and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥6,262.321 (in millions). Households need to work 243 days for soybean and peanut.

Table 20: Efficient Allocation of Soybean and Peanut in Jilin, China (WE)

	Soybean	Peanut	Borrow			
Opt Value	11.05	22.19	979	Revenue		
Gross Revenue	48.3	260.12	(4.35%)	6,262.321		
Constraint				LHS	Relationship	RHS
Land	1	1	0	33.23	<=	85
Lab Soybean	22	0	0	243	<=	243
Lab Peanut	0	9.6	0	213	<=	213
Capital	758.30	836.7	-1	25,960.61	<=	86,079
Loan	0	0	1	979	>=	979

Table 21 presents the efficient allocation of corn and rice in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥20,616.66 (in millions). Households need to work 213 days for corn and rice.

Table 21: Efficient Allocation of Corn and Rice in Jilin, China (WE)

	Corn	Rice	Borrow			
Opt Value	59.17	13.07	979	Revenue		
Gross Revenue	244.54	473.6	(4.35%)	20,616.66		
Constraint				LHS	Relationship	RHS
Land	1	1	0	72.24	<=	85
Lab Corn	3.6	0	0	213	<=	213
Lab Rice	0	14	0	183	<=	183
Capital	728.92	1,339.0	-1	59,651.41	<=	86,079
Loan	0	0	1	979	>=	979

Table 22 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥20,197.44 (in millions). Households need to work 213 days for corn and peanut.

Table 22: Efficient Allocation of Corn and Peanut in Jilin, China (WE)

	Corn	Peanut	Borrow			
Opt Value	59.17	22.19	979	Revenue		
Gross Revenue	244.54	260.12	(4.35%)	20,197.44		
Constraint				LHS	Relationship	RHS
Land	1	1	0	81.35	<=	85
Lab Corn	3.6	0	0	213	<=	213
Lab Peanut	0	9.6	0	213	<=	213
Capital	728.92	836.7	-1	60,712.6	<=	86,079
Loan	0	0	1	979	>=	979

Table 23 presents the efficient allocation of rice and peanut in Jilin, China. Households allocate 13.07 hectares (in millions) for rice, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥11,919.45 (in millions). Households need to work 213 days for rice and peanut.

Table 23: Efficient Allocation of Rice and Peanut in Jilin, China (WE)

	Rice	Peanut	Borrow			
Opt Value	13.07	22.19	979	Revenue		
Gross Revenue	473.6	260.12	(4.35%)	11,919.45		
Constraint				LHS	Relationship	RHS
Land	1	1	0	35.26	<=	85
Lab Rice	14	0	0	183	<=	183
Lab Peanut	0	9.6	0	213	<=	213
Capital	1,339.0	836.7	-1	35,087.48	<=	86,079
Loan	0	0	1	979	>=	979

4.2.Linear Programming Results with Government Regulations Effect

The Central Document No. 1 originally referred to the first document issued by the Central Committee of the Communist Party of China (CPC). On October 1, 1949, the Central People's Government of the People's Republic of China began to issue the "No. 1 Document." Now it has become the proper term for the CPC Central Committee to attach importance to rural issues. The Central Committee of the Communist Party of China issued the Central Document No. 1 on agriculture, rural areas and farmers for five consecutive years from 1982 to 1986, making concrete arrangements for rural reform and agricultural development. From 2004 to 2018, for the 15 consecutive years, the Central Document No. 1 with the theme of "Three Rural Issues" (Agriculture, Rural Areas, and Peasants) was issued, emphasizing that the issue of "agriculture, rural areas and farmers" was "the most important thing" during the period of socialist modernization in China. Table 24 provides an overview of the Central Document No. 1 from 2013 to 2018.

Table 24: The Central Document No. 1 from 2013 to 2018

YEAR	NAME	SIGNIFICANCE
2013	Several Opinions of the Central Committee of the Communist Party of China and the State Council on Accelerating the Development of Modern Agriculture and Further Enhancing the Vitality of Rural Development	Stress the construction of modern agriculture, give full play to the superiority of the basic management system, and focus on building a new agricultural management system.
2014	Several Opinions on Comprehensively Deepening Rural Reform and Accelerating Agricultural Modernization	Further emancipate the mind, strive for progress, reform and innovation, resolutely break the shortcomings of the system and mechanism, adhere to the unswerving position of the agricultural foundation, and accelerate the agricultural modernization

2015	Several Opinions on Increasing Reform and Innovation and Accelerating Agricultural Modernization Construction	At present, China's economic development has entered a new normal, shifting from high-speed growth to medium-high-speed growth. How to continue to strengthen the basic position of agriculture and promote the continuous increase of farmers' income in the context of slowing economic growth is a major issue that must be solved.
2016	Several Opinions of the Central Committee of the Communist Party of China and the State Council on Implementing the New Concept of Development and Accelerating Agricultural Modernization	Promote the reform and development of rural areas, adhere to the policy of strengthening agriculture, benefiting farmers and enriching agriculture, and promote the building of a comprehensive well-off society in rural areas. Accelerate the development of modern agriculture, the increase of farmers' income, and the construction of a new socialist countryside, and continuously consolidate and develop a good situation in agriculture and rural areas.
2017	Several Opinions of the Central Committee of the Communist Party of China and State Council on Further Promoting the Structural Reform of	Optimize the product industry structure, focus on promoting agricultural quality and efficiency; Promote green production methods, enhance the sustainable development of agriculture; Expand new industries and new business forms, expand

	Agricultural Supply Side and Accelerating the Cultivation of New Developmental Motive Forces of Agricultural and Rural Development	the value chain of agricultural industry chains; Strengthen the drive of scientific and technological innovation, and lead the development of modern agriculture; Fill up agriculture and rural short-board, consolidate the basis of rural shared development; Increase rural reform efforts, activate the endogenous development momentum of agriculture and rural areas.
2018	Opinions on Implementing the Rural Revitalization Strategy	The implementation of the rural revitalization strategy is a major decision-making arrangement made by the Party's 19^{th} National congress. It is a major historical task for building a well-off society and socialist modern country in an all all-round way. It is the general grasp of the work of the "Three Rural Issues" in the new era.

Resources: Ministry of Agriculture and Rural Affairs of the People's Republic of China

The issue of agricultural, rural areas, and peasants is a fundamental one related to the national economy and the people's livelihood. Without the modernization of agriculture and rural areas, there would be no modernization of the country. At present, the problem of insufficient development and inequality in China is most prominent in rural areas, mainly in the following stages: rural infrastructure and high debt levels, prominent rural environment and ecological problems, the insufficient overall level of rural development. Therefore, the Chinese government provides subsidies to help rural land-renting, and provides agricultural poverty alleviation funds, agricultural discount loans and large-scale subsidies for planting crops.

Table 25 provides an overview of basic information in the model computation III for the major four crops, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥844.1 for soybean, ￥980.33 for corn, ￥1,703.1 for rice, ￥1,096.8 for peanut; the gross revenue is ￥373.4 for soybean, ￥301.42 for corn, ￥909.4 for rice, and ￥644.12 for peanut.

Table 25 Grains Gross Revenue Computation III

	SOYBEAN	CORN	RICE	PEANUT
VALUE PER HECTARE	675.3	980.33	1703.1	1096.8
SUBSIDIES PER HECTARE	168.8	--------	--------	--------
EXPECTED REVENUE	844.1	980.33	1703.1	1096.8
FERTILIZER	63.8	183.28	131.6	130.22
PESTICIDE	22.9	18.57	24.9	32.4
SEED	32.9	56.21	34.0	110.2
MACHINERY RENT	93.9	89.54	158.0	118
LABOR COST	257.2	331.31	445.2	61.86
LANDING RENT	--------	--------	--------	--------
TOTAL VARIABLE COST	470.7	678.91	793.7	452.68
GROSS REVENUE	373.4	301.42	909.4	644.12

Sources: Various Jilin Government Report Computation

4.2.1. Optimization

Table 26 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 59.17 hectares (in millions) for corn, which can make a maximum revenue at ￥21,919.23 (in millions). Households need to work 243days for soybean and corn.

Table 26: Efficient Allocation of Soybean and Corn in Jilin, China (GE)

	Soybean	Corn	Borrow			
Opt Value	11.05	59.17	979	Revenue		
Gross Revenue	373.4	301.42	(4.00%)	21,919.23		
Constraint				LHS	Relationship	RHS
Land	1	1	0	70.21	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Corn	0	3.6	0	213	<=	213
Capital	470.7	678.91	-1	44,388.94	<=	86,079
Loan	0	0	1	979	>=	979

Table 27 presents the efficient allocation of soybean and rice in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥15,972.37 (in millions). Households need to work 243 days for soybean and rice.

Table 27: Efficient Allocation of Soybean and Rice in Jilin, China (GE)

	Soybean	Rice	Borrow			
Opt Value	11.05	13.07	979	Revenue		
Gross Revenue	373.4	909.4	(4.00%)	15,972.37		
Constraint				LHS	Relationship	RHS
Land	1	1	0	24.12	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Rice	0	14	0	183	<=	183
Capital	470.7	793.7	-1	14,594.89	<=	86,079
Loan	0	0	1	979	>=	979

Table 28 presents the efficient allocation of soybean and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥18,376.63 (in millions). Households need to work 243 days for soybean and peanut.

Table 28: Efficient Allocation of Soybean and Peanut in Jilin, China (GE)

	Soybean	Peanut	Borrow			
Opt Value	11.05	22.19	979	Revenue		
Gross Revenue	373.4	644.12	(4.00%)	18,376.63		
Constraint				LHS	Relationship	RHS
Land	1	1	0	33.23	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Peanut	0	9.6	0	213	<=	213
Capital	470.7	452.7	-1	14,263.93	<=	86,079
Loan	0	0	1	979	>=	979

Table 29 presents the efficient allocation of corn and rice in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥29,682.01 (in millions). Households need to work 213 days for corn and rice.

Table 29: Efficient Allocation of Corn and Rice in Jilin, China (GE)

	Corn	Rice	Borrow			
Opt Value	59.17	13.07	979	Revenue		
Gross Revenue	301.42	909.4	(4.00%)	29,682.01		
Constraint				LHS	Relationship	RHS
Land	1	1	0	72.24	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Rice	0	14	0	183	<=	183
Capital	678.91	793.7	-1	49,564.63	<=	86,079
Loan	0	0	1	979	>=	979

Table 30 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥32,085.27 (in millions). Households need to work 213 days for corn and peanut.

Table 30: Efficient Allocation of Corn and Peanut in Jilin, China (GE)

	Corn	Peanut	Borrow			
Opt Value	59.17	22.19	979	Revenue		
Gross Revenue	301.42	644,12	(4.00%)	32,086.27		
Constraint				LHS	Relationship	RHS
Land	1	1	0	81.35	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Peanut	0	9.6	0	213	<=	213
Capital	678.91	452.7	-1	49,234.12	<=	86,079
Loan	0	0	1	979	=	979

Table 31 presents the efficient allocation of rice and peanut in Jilin, China. Households allocate 13.07 hectares (in millions) for rice, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥26,139.41 (in millions). Households need to work 213 days for rice and peanut.

Table 31: Efficient Allocation of Rice and Peanut in Jilin, China (GE)

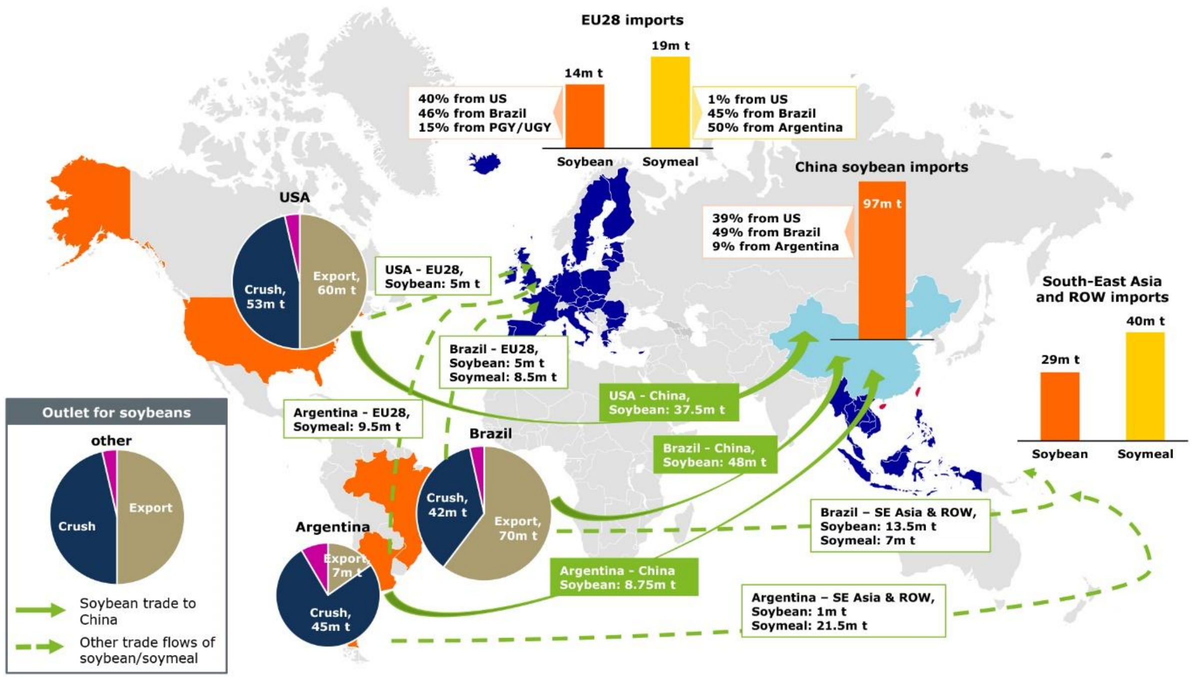
	Rice	Peanut	Borrow			
Opt Value	13.07	22.19	979	Revenue		
Gross Revenue	909.4	644.12	(4.00%)	26,139.41		
Constraint				LHS	Relationship	RHS
Land	1	1	0	35.26	<=	105
Lab Rice	14	0	0	183	<=	183
Lab Peanut	0	9.6	0	213	<=	213
Capital	793.7	452.7	-1	19,440.07	<=	86,079
Loan	0	0	1	979	>=	979

4.3. Linear Programming Results with Trade War Effects

On April 4, 2018, the Ministry of Commerce issued the No. 34 announcement in 2018, which will impose tariffs on imported products such as soybeans and other agricultural products, automobiles, chemicals, and aircraft originating in the United States, with a tax rate of 25%. In 2017, China imported the products of about 50 billion US dollars from the United States.

On April 17, 2018, the Ministry of Commerce issued Announcement No. 38 of 2018 to announce the preliminary ruling on the anti-dumping investigation against imported sorghum originating in the United States. The Ministry of Commerce ruled that the import sorghum originating in the United States was dumped, the domestic sorghum industry suffered substantial damage, and there was a causal relationship between dumping and substantial damage, and decided to implement temporary anti-dumping measures against imported sorghum originating in the United States. Figure 4 presents that China imports 60% of global soybeans. 39% of Chinese soybean imports are from U.S., 49% from Brazil and 9% from Argentina.

Figure 4: The Severe Implications of Soybean Tariffs

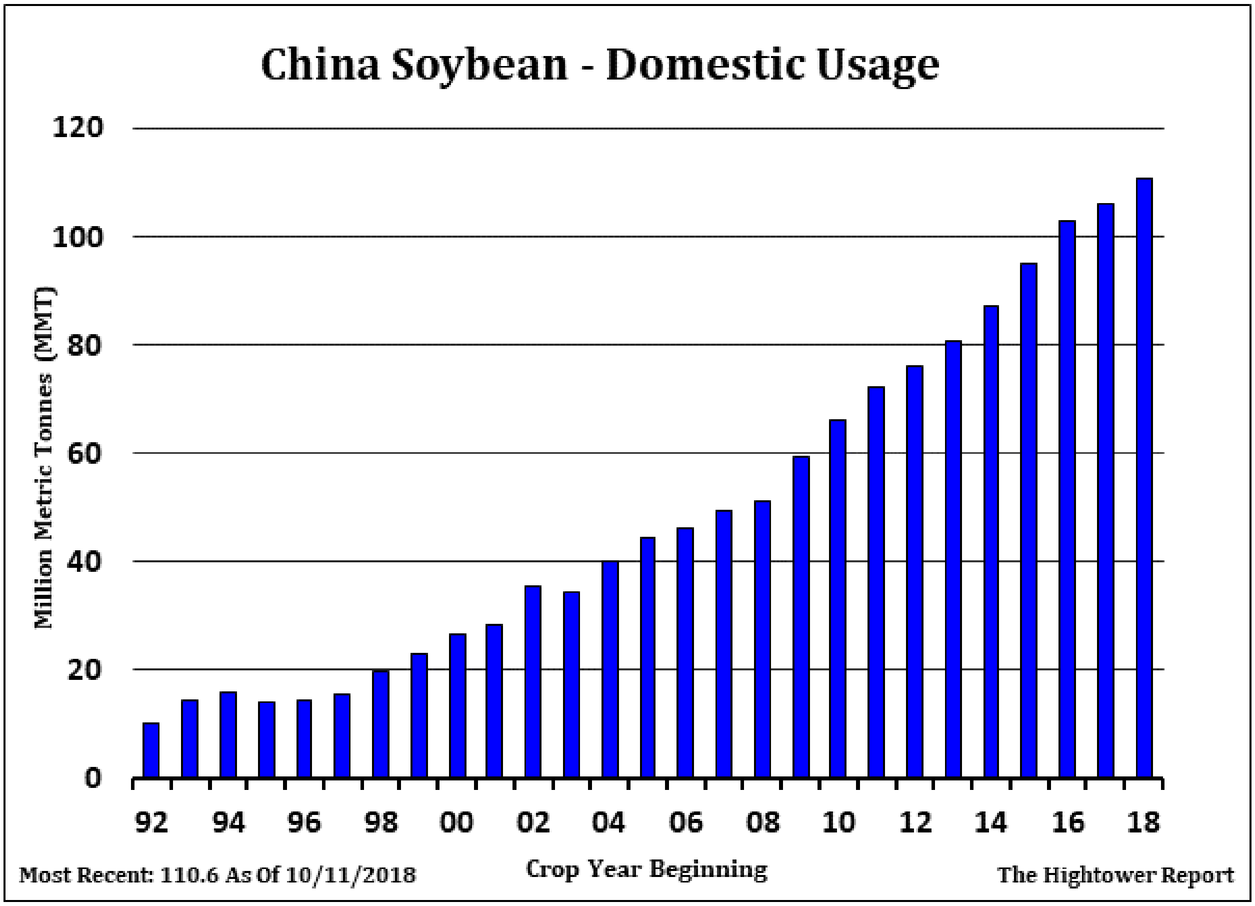


Source: USDA, UN Comtrade, Rabobank 2018

Source: AGWEB

With an additional 25 % duty on the soybean imports from the U.S., the imports from the U.S. fell and the imports from Brazil and Argentina increased, but China's soybean consumption is still increasing and the imports growth from Brazil and Argentina cannot fill gaps in the domestic market, which will cause the domestic soybean prices to increase. Figure 5 presents the China's soybean consumption from 1992 to 2018, although the growth rate has slowed in the last two years, China soybean consumption is still in the highest position, 110 MMT in the 2018.

Figure 5: China Soybean – Domestic Usage



Resource: CME Group

Table 32 provides an overview of basic information for the model computation IV for the major four crops, which includes value per hectare, subsidies per hectare, expected revenue, fertilizer cost, pesticide cost, seed cost, machinery rent, labor cost, landing rent and gross revenue. The expected revenue is ￥844.1 for soybean, ￥982.32 for corn, ￥1,403.3 for rice, ￥810.68 for peanut; the gross revenue is ￥312.4 for soybean, ￥358.14 for corn, ￥313.5 for rice, and ￥174 for peanut.

Table 32: Grains Gross Revenue Computation IV

	SOYBEAN	CORN	RICE	PEANUT
VALUE PER HECTARE	675.3	982.32	1403.3	810.68
SUBSIDIES PER HECTARE	168.8	--------	--------	--------
EXPECTED REVENUE	844.1	982.32	1403.3	810.68
FERTILIZER	63.8	178.54	131.6	130.22
PESTICIDE	22.9	17.93	24.9	32.4
SEED	32.9	47.92	34.0	110.2
MACHINERY RENT	93.9	139.3	158.0	118
LABOR COST	157.2	45.3	445.2	61.86
LANDING RENT	160	195.19	296.1	184
TOTAL VARIABLE COST	531.7	624.18	1089.8	636.68
GROSS REVENUE	312.4	358.14	313.5	174

Sources: Various Jilin Government Report Computation

4.3.1. Optimization

Table 33 presents the efficient allocation of soybean and corn in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 59.17 hectares (in millions) for corn, which can make a maximum revenue at ￥24,597.96 (in millions). Households need to work 243days for soybean and corn.

Table 33: Efficient Allocation of Soybean and Corn in Jilin, China (TE)

	Soybean	Corn	Borrow			
Opt Value	11.05	59.17	979	Revenue		
Gross Revenue	312.4	358.14	(4.35%)	24,597.96		
Constraint				LHS	Relationship	RHS
Land	1	1	0	70.21	<=	105
Lab Soybean	22	0	0	243	<=	243

Lab Corn	0	3.6	0	213	<=	213
Capital	531.7	624.18	-1	41,824.52	<=	86,079
Loan	0	0	1	979	>=	979

Table 34 presents the efficient allocation of soybean and rice in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥7,505.906 (in millions). Households need to work 243 days for soybean and rice.

Table 34: Efficient Allocation of Soybean and Rice in Jilin, China (TE)

	Soybean	Rice	Borrow			
Opt Value	11.05	13.07	979	Revenue		
Gross Revenue	312.4	313.5	(4.35%)	7,505.906		
Constraint				LHS	Relationship	RHS
Land	1	1	0	24.12	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Rice	0	14	0	183	<=	183
Capital	531.7	1089.8	-1	19,139.11	<=	86,079
Loan	0	0	1	979	>=	979

Table 35 presents the efficient allocation of soybean and peanut in Jilin, China. Households allocate 11.05 hectares (in millions) for soybean, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥7,269.08 (in millions). Households need to work 243 days for soybean and peanut.

Table 35: Efficient Allocation of Soybean and Peanut in Jilin, China (TE)

	Soybean	Peanut	Borrow			
Opt Value	11.05	22.19	979	Revenue		
Gross Revenue	312.4	174	(4.35%)	7,269.08		
Constraint				LHS	Relationship	RHS
Land	1	1	0	33.23	<=	105
Lab Soybean	22	0	0	243	<=	243
Lab Peanut	0	9.6	0	213	<=	213
Capital	531.7	636.68	-1	19,020.21	<=	86,079
Loan	0	0	1	979	>=	979

Table 36 presents the efficient allocation of corn and rice in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 13.07 hectares (in millions) for rice, which can make a maximum revenue at ￥25,245.26 (in millions). Households need to work 213 days for corn and rice.

Table 36: Efficient Allocation of Corn and Rice in Jilin, China (TE)

	Corn	Rice	Borrow			
Opt Value	59.17	13.07	979	Revenue		
Gross Revenue	358.14	313.5	(4.35%)	25,245.26		
Constraint				LHS	Relationship	RHS
Land	1	1	0	72.24	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Rice	0	14	0	183	<=	183
Capital	624.18	1089.8	-1	50,196.89	<=	86,079
Loan	0	0	1	979	>=	979

Table 37 presents the efficient allocation of corn and peanut in Jilin, China. Households allocate 59.17 hectares (in millions) for corn, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥25,007.99 (in millions). Households need to work 213 days for corn and peanut.

Table 37: Efficient Allocation of Corn and Peanut in Jilin, China (TE)

	Corn	Peanut	Borrow			
Opt Value	59.17	22.19	979	Revenue		
Gross Revenue	358.14	174	(4.35%)	25,007.99		
Constraint				LHS	Relationship	RHS
Land	1	1	0	81.35	<=	105
Lab Corn	3.6	0	0	213	<=	213
Lab Peanut	0	9.6	0	213	<=	213
Capital	678.91	636.68	-1	53,316.18	<=	86,079
Loan	0	0	1	979	=	979

Table 38 presents the efficient allocation of rice and peanut in Jilin, China. Households allocate 13.07 hectares (in millions) for rice, 22.19 hectares (in millions) for peanut, which can make a maximum revenue at ￥7,915.931 (in millions). Households need to work 213 days for rice and peanut.

Table 38: Efficient Allocation of Rice and Peanut in Jilin, China (TE)

	Rice	Peanut	Borrow			
Opt Value	13.07	22.19	979	Revenue		
Gross Revenue	313.5	174	(4.35%)	7,915.931		
Constraint				LHS	Relationship	RHS
Land	1	1	0	35.26	<=	105
Lab Rice	14	0	0	183	<=	183
Lab Peanut	0	9.6	0	213	<=	213
Capital	1,089.8	636.68	-1	27,392.58	<=	86,079
Loan	0	0	1	979	>=	979

5. CONCLUSIONS

This thesis designs a linear programming model to conduct an analysis of efficient allocation of resources in the grain industries in Jilin, China. I examine what role the government regulations play in the grain production in China and how the trade war affects the grain production. The results and policy implications of this study can be useful for improving future agricultural structure, rational cultivation of grains, and market prediction for Jilin, China.

In general, in order to make a maximum revenue, households need choose corn and rice to plant in the following years. Under the effects of weather, government regulations, and trade war, planting corn and rice is still the first choice. Although planting corn and peanut may make a maximum revenue with the government regulations effects under certain conditions, there is a large fluctuation, especially in land renting. When the land renting is lower than the average line, households can make more revenue and vice versa. However, a major problem is how to convince the farmers to plant corn and rice, they may not necessarily believe that our linear approach can let them make more money than before, therefore, it is necessary to deepen the reform of the agricultural science and technology system, introduce targeted reform incentive policies, improve the use, disposal and income management systems for agricultural scientific and technological achievements, and mobilize the enthusiasm of agricultural research units and researchers. We must promote the construction of an agricultural innovation system and build a platform for agricultural collaborative innovation.

Whether it is weather effects, or government regulation effects, or trade war effects, they can reduce each constraint on the surface, but actually affect the grain prices. For the weather effects, the planting area near the coastal regions will decrease and the crop outputs will decrease, and then the grain prices will increase. For the government regulation effects, the rural land-renting counties are subsidized. If engaged in planting, households will receive the government's agricultural poverty alleviation funds, agricultural discounted loans, and large-scale subsidies for planting, so the crop outputs will increase and the grain prices will decrease. But for the situation when households produce both grain and livestock, some of our results need to be reconsidered. As we know, most of the livestock feeds is made up of soybeans and corn. When the crop outputs decrease and the grains prices increase, farmers will receive government subsidies for crop planting, but it will cost more for farmers to feed their livestock. The benefits of crop planting may not compensate for the higher cost of livestock product. Farmers will re-consider their optimal crop-planting decisions when they are involved in both crop and livestock production.

For the trade war effects, China's soybean consumption is still increasing, but the import growth from Brazil and Argentina cannot fill gaps in the domestic market. Thus, the domestic soybean prices will continue to increase.

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