THREE ESSAYS ON AGRICULTURAL POLICY AND FOOD DEMAND

A Dissertation

presented to

the Faculty of the Graduate School

at the University of Missouri-Columbia

In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

by

JING ZHAO

Dr. Wyatt Thompson, Dissertation Supervisor

DECEMBER 2015

The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

THREE ESSAYS ON AGRICULTURAL POLICY

AND FOOD DEMAND

presented by Jing Zhao, a candidate for the degree of doctor of philosophy, doctor of Agricultural and Applied Economics,

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor Wyatt Thompson

Professor William Meyers

Professor Isaac Miller

Professor Julian Binfield

Professor John Kruse

ACKNOWLEDGEMENTS

I would like to express my deepest appreciation to my advisor, Dr. Wyatt Thompson. I remember that I knew him when I took Dr. Womack's Summer Modeling Course in summer 2011. Since then, he directed me on the way to be an excellent economist. I thank him for his intellectual advice and constant support, both in research and in my family life. I am greatly indebted to him since the dissertation would not have been possible without his tremendous help. In my heart, he is not only an advisor but also a father figure.

To my committee members, Dr. William Meyers, Dr. Isaac Miller, Dr. Julian Binfield, Dr. John Kruse, I would express my gratitude for their comments and insights on dissertation draft and at the defense. I thank Dr. William Meyers for bringing me the opportunity to study at the University of Missouri and so much help he had given me. I met him in China in summer 2009, and he always encouraged me to move further toward an agricultural economist. I thank Dr. Isaac Miller for his critical views for my research. I took two econometrics class of Dr. Miller, from which I received solid training in applying econometric methods to solve real economic problems. He was always supportive whenever I had problems in the empirical research. I also thank Dr. John Kruse, who provided me an excellent opportunity to work as an intern at IHS Global Insight, where I received hands-on experience of commodity market modeling and forecasting in coordination with other team members. I thank Dr. Julian Binfield for giving me a lot of detailed comments on my dissertation draft.

I thank my colleagues at IHS Global Insight, Ryland Maltsbarger, Robert Maltsbarger, Pon Intarapopong, Brandon Kliethermes, Ryan Koory, and Al Melhim. I worked with them for almost three years, 20 hours per week. During the coffee break or lunch time, we talked about all kinds of topics, covering agriculture market, economics, history, environment, culture differences between China and US, food, kids, education, etc. They also helped me to overcome the language transition from China to US.

I thank my classmates, Ye Su, Jingjing Wang, Hoa Hoang, Jarrett Whistance for studying together and sharing. My special thanks go to Jingjing Wang. She took care of me when my health was bad and gave me countless support in my study and life. I also want to thank other friends at MU, Weirong Chen, Bolei Ni, Hua Bai, Jiaxi Li, Xi Wang, Boxu Zhou.

I would like to extend my deepest appreciation to my family, especially my parents and little sister, who always give me unconditional support and love, whenever I need them. I appreciate that my parents can help me take care of my daughter Agnes when my husband and I are both on the way to be PhDs. They brought so many happiness and laughs to Agnes and us.

Last but not the least, I would like to thank my husband Xiaobin for sharing all in life with me and giving me support. I am so grateful to have such a lovely daughter, Agnes. She always brings us happiness and hope. It is the most beautiful thing to have them in my life.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1 Using Income Growth to Extrapolate Future Wheat Producer Support

Chapter 2 The Influences of Wheat Government Stock Policy in China: A Counterfactual Analysis

Chapter 3 The Effect of Refrigerator Use on food Consumption in Rural China

LIST OF FIGURES

Chapter 1 Using Income Growth to Extrapolate Future Wheat Producer Support

Chapter 2 The Influences of Wheat Government Stock Policy in China: A Counterfactual Analysis

ABSTRACT

To understand better the effect of policy and technology on agricultural markets, I study three topics about agricultural policy and food demand in this dissertation. My first essay identifies the worldwide historical pattern of wheat support and predicts the future trend of wheat support. Based on the theory of political economy, it is proposed that the income level is one factor that determines agricultural support. To provide the empirical evidence to substantiate this theory, I test the relationship between wheat support and income by building a fixed effect model with the historical data of 55 countries from 1961 to 2011. Besides income, several other factors are also considered, including three dummies for food spikes, trade status, per capita arable land area, agricultural population rate, and a shift variable that serves as a proxy for Uruguay Round Agreement Act implementation. The results indicate that there are statistically significant effects of income, income square, and income cubed on wheat support. In addition, I project that the future wheat support levels of China and India, especially border market support, might continue to rise with income growth. Meanwhile, Japan might maintain its high level of wheat support into the future.

In the second essay, I examine the effect of government stock policies on the outcomes of China wheat market. Since 2006, the Chinese government used strategic reserve and marketing auctions to influence wheat market outcomes. Yet relatively little is known about how these policies affect wheat market prices in China. I develop and use a structural economic model to conduct a counterfactual analysis in this study. I evaluate the wheat market effects of government marketing activities during the period 2006/07 to 2013/14. I also perform sensitivity analysis to estimate the impacts of alternative

displacement degrees between government stocks and private stocks, domestic area response, corn prices changes, and alternative price elasticities of stock demand. The results indicate that the government stock policies stabilized wheat market prices, if measured by the standard deviation of annual prices, and raised the wheat production in China over the year 2006-2013.

In the third essay, I assess the effects of new technology adoption on food consumption. I test the effect of refrigerator ownership on food consumption in rural China during the period when the refrigerator ownership in rural China increased from 14% in 2001 to 45% in 2010. I use two methods to develop models and perform empirical tests. First, I estimate two-way fixed effect model based on single-equation demand function that explains consumption using own price, cross prices, and household characteristics. The results show that refrigerator ownership had a statistically significant and negative effect on meat consumption quantities. Annual meat consumption per capita would decrease 1 kilogram with 1% increase in refrigerator ownership rate. Second, I develop a demand system model, and link refrigerator ownership to food expenditure in an auxiliary equation. The results indicate that refrigerator ownership has a statistically significant and negative effect on total food expenditure, while it has a statistically significant and positive effect on the expenditure share of meat, egg, seafood, and negative effect on grain and fruit. Moreover, without considering refrigerator, the price and income elasticities of different food might be overestimated or underestimated. Taking meat for example, the income elasticity might be overestimated without considering refrigerator, which might lead to higher meat demand projection in the future with income growth. Therefore, I conclude that refrigerator ownership might reduce total food expenditure and

meat consumption quantity, and that refrigerators may change food consumption pattern, by increasing the expenditure share of meat, egg, seafood, and decreasing the food expenditure share of grain, fruits, that the future food demand projection in rural China might be biased without considering refrigerator ownership. To enumerate a few underlying reasons that could lead to these results, refrigerators might help reduce the food losses or waste by changing the way people store food, the frequency with which people buy food, and the food mix people consume. This study might provide evidence on some of the benefits and costs of subsidizing the purchases of refrigerators in the developing countries.

CHAPTER 1 USING INCOME GROWTH TO EXTRAPOLATE FUTURE WHEAT PRODUCER SUPPORT

1.1 Introduction

Wheat is produced in around 120 countries, with China, India, the United States, Russia, France, Australia, and Canada as major producing countries. Although the production in China and India accounts for 30% of world total production, their wheat consumption exceeds production in some years, leading to wheat imports. All major wheat exporting countries are developed countries, such as the United States, France, Canada, Australia, and Germany. In contrast, wheat importing countries are widely dispersed around the world, with Egypt, Algeria, Italy, Japan, Brazil, and Indonesia being important importing countries. Being an important staple product, wheat has been treated as a strategic food, so most developed countries as well as some developing countries aimed to assure wheat supplies and protect their wheat industry. Thus, it is essential to understand how agricultural policies evolved as countries developed.

World food price spikes happened more often last decade (2006-08 and 2010-11) than in the preceding several decades, especially for wheat and rice. During the food crises, such as 1973-74, 1986-88, and 2006-08, many countries tried to insulate their domestic market from the international market to stabilize the wheat price, which brought more volatility to world wheat market. High food price was harmful to poor consumers, potentially causing malnutrition, hunger and even death.

This paper uses world agricultural distortion data from the World Bank and the dynamic panel data model to test the relationship between agricultural support level and rising

income, trade status, agricultural population rate, per capita arable land area, and historical food crises. It adds to the literature in the area of agricultural policy evolution with income growth all over the world, especially in wheat support polices. The results suggest that wheat support has significant relationship with income, income per capita square, and income per capita cubed, instead of a simple upward or downward trend; that the majority part of wheat support is tied to output; the support from border measures is highly related to income growth while the support from domestic market support has little to do with the income growth; that most wheat countries' policies seem to work against the interests of wheat producers during food price spikes and protect producers during the food price slumps; and that country-specific factors, like natural resources, and the political system, might affect wheat support significantly. These findings could explain how wheat support evolves as incomes grow and are particularly important in the context of long-run projections of agricultural markets, which are necessary for many studies of climate change and food security in the future.

1.2 Literature Review

Government interventions in the wheat industry vary a lot among the developed, less developed and developing countries. Even in the same country, agriculture policies changed as the country moved from one phase of economic development to another. In less developed or developing countries, agriculture tended in the past to be taxed while developed countries were more likely to subsidize their agriculture (Peterson 1979, Bale and Lutz 1981, Anderson 1995). This pattern might not be continuous, as at least anecdotal evidence suggested that rising income no longer leads to rising support at some point. For instance, Thompson, Gohout, and Herrmann (2002) describe that the CAP

policy regime of the European Union during the years 1976 to 1992 was implemented to support farm income at a high and stable wheat price, and the governments had to buy wheat at the intervention price, store it and sell it to the world market with a loss, or pay private exporters the difference between export price and intervention price. High import taxes were levied to isolate the domestic market from world wheat market. These authors also note that the composition of support was not the same at all times. However, after 1992, the EU reduced the domestic price support and relied more upon market forces (Barassi and Ghoshray 2007). The United States had commodity loan programs since the 1930s, crop and revenue insurance since 1994, production flexibility contract payments instead of the target price and deficiency payment program starting in 1996, disaster assistance for crop losses, direct "market loss assistance" in some years after 1998, public stock holding, and research expenditures in the wheat sector (Oehmke and Yao 1990, Young and Westcott 2000). The US farm bill of 2014 replaces some crop policies tied to historical base areas with new programs that are similar, but apparently more sensitive to market conditions (USDA 2014). Before 2000, China levied an agriculture tax on wheat production and the agricultural policies changed a lot after China's accession into WTO in 2001 Since 2006, the Chinese government has provided direct payments to wheat farmers, increased subsidies to fertilizer and other inputs, increased subsidies to adopt improved seeds, and improved minimum procurement price (Yu and Jensen 2010). Given these facts, we hypothesized that government interventions in the wheat industry are related to the income level or the development period in economic growth.

Most countries intervened in the wheat market during the food crises in the recent past. Wheat export restrictions in some exporting countries and reduced import tariff in many

importing countries were employed during the food crisis 1973-74 and 2006-08, which magnified the international price surge rather than stabilized world price (Demeke, Pangrazio, and Maetz 2008, Headey 2011, Anderson et al. 2008).

Several studies investigate trade policy, price formation, and price characteristics in world wheat market (McCalla 1966, Shei and Thompson 1977, Alaouze, Watson, and Sturgess 1978, Carter and Schmitz 1979, Paarlberg and Abbott 1986, Ghoshray 2002, Sekhar 2003, Gómez-Plana and Devadoss 2004). McCalla (1966), Taplin (1969), and Alaouze, Watson, and Sturgess (1978) hypothesize that the world wheat market is oligopolistic and they propose that price formation in the world wheat market is influenced by the exporters. Carter and Schmitz (1979) argue that world wheat market price is determined by the major wheat importers. Shei and Thompson (1977) provide empirical evidence that trade restrictions exaggerate the price fluctuations in the world wheat market. Larue and Lapan (1992) indicate that a wheat exporting country with more firms is more likely to have low quality wheat compared to those with sole exporter due to the free riding. Abbott and Young (1999) investigate the impact of wheat-importing state trading enterprises on the world wheat market. Sekhar (2003) identifies the determinants of price formation and the influence of major exporters on the stability of world wheat markets through the two-sector model. Baek and Koo (2006) recognize the structural change and tested price dynamics using Perron's test, Johansen Cointegration analysis, and Vector Error Correction model.

However, there are only few studies that attempt to explore the distortion patterns as well as the influencing factors in world wheat market, with specific reference to income level in order to support forward-looking analysis. For example, Anderson and Nelgen (2012)

examine the influencing factors of government behaviors on nominal rates of assistance (NRAs) of six key crop products, including rice, wheat, maize, soybean, sugar and cotton, in order to determine the extent of insulation that governments applied onto their domestic agricultural markets. The explanatory variables included logarithm of real gross domestic product (GDP) per capita, logarithm of real GDP per capita squared, logarithm of arable land per capita, percent deviation of international price from its trend, and a dummy for trade status. The regressions are estimated by ordinary least squares (OLS) for 75 countries with the data from 1955-2011 without country fixed effects. Their results indicate that NRAs tended to grow as a country's per capita income rose, and NRAs grew more with a decline in agricultural comparative advantage; that agricultural policy tended to protect import industries and did not restrict exports; and that NRAs had a negative relationship with the deviations from trend in the international price. However, their study uses pooled data without fixed effects, so one could not exclude the possibility that there is a bias caused by omitted variables, such as climate, geography, or political system, which are likely to exert the effect on the explanatory variable in their regressions. Anderson and Nelgen (2012) represent a key study in this area, and an important point of reference for the present study. In the current study, I extend their work regarding how agricultural support in wheat evolves with income growth, trade status, agricultural population rate, and food price spikes using a fixed effect method and made projections to support forward-looking analysis.

1.3 Data

1.3.1 Measuring distortions to wheat market

Several ways exist to measure the policy distortions to world wheat market, including Producer Support Estimates (PSE) and Consumer Support Estimates (CSE) from the Organization for Economic Cooperation and Development (OECD), Nominal Rate of Assistance (NRA) from the World Bank, and Nominal Rate of Protection (NPR) from the Food and Agriculture Organization (FAO). In order to compare a large set of countries for as many years as possible, this study follows the methods of Anderson et al. (2008) and Anderson (2010) in measuring agricultural distortions by using Nominal Rate of Assistance (NRA), Nominal Rate of Assistance to output (NRA_o), and Nominal Rate of Assistance to input (NRA_i). The outcome variables in this study include NRA and its components. NRA is defined as the percentage share by which government policies increase (or decrease) gross returns to producers compared to what the returns would have been received at world prices, adjusted for transportation costs. If governments raise gross returns to farmers, such as using price support, then NRA is positive. NRA is negative if agricultural production is taxed by the government, such as using an agricultural output tax or an export tax. NRA_o is nominal rate of assistance to output, which includes support provided by both border market price (NRA_bms) and domestic price support (NRA_dms). NRA_i is nominal rate of assistance to inputs, such as fertilizer, seeds, and agriculture machinery. All the data used in this paper come from the World Bank Agriculture Distortion database, which provided NRA data in 75 focus countries from 1955 to 2011.

1.3.2 Wheat distortions in the major producing countries

The United States, Australia, Canada, and France are major wheat exporting countries, while China and India are the two countries that account for the largest share of world wheat production. Thus, data of these six countries are useful for us to discern the world wheat policy trends. From Figure 1, France, as a representative of EU countries, has the most intervention in the wheat industry among the six countries mentioned above, according to these data. China and India provide the most assistance to their wheat industries in recent years, by these measures. Especially after 2000, most developed countries intervene little in the wheat industry, while China and India still take measures to stimulate wheat production and raise producers' gross returns. Canada is a net exporting country of wheat with minor intervention in the wheat market, except during 1986-88 when the world food price slumped. In this historical period, Australia, another major exporting country, also intervened somewhat in the wheat industry.

During the food crisis of 1973-74, the gross returns of wheat producers in France, US, Australia and India were lower than their returns would have been if evaluated at world prices. During the 1986-88 period, the nominal rates of assistance to wheat producers in all these six countries were greater than 0, even more than 1 for France, which indicated that these wheat producing countries protected their producers.

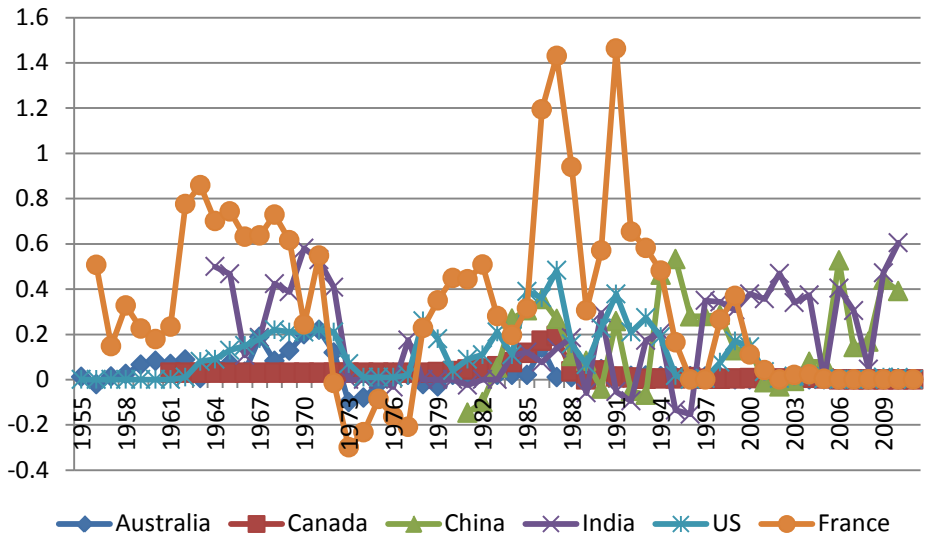

Figure 1 Nominal Rate of Assistance (NRA) for wheat in major countries
Source: World Bank Agriculture Distortion Database (2011)

1.4 Method

Based on the findings in the literature, as discussed above, this study proposes that agricultural distortions might be related to income level, world food price crises, trade status, land area per capita and agricultural population share. I use the panel data model with fixed effect method, which could control for unobservable or immeasurable variables, like cultural factors, distinct resource endowment, climate and geography characteristics, political system and customs. The underlying assumption behind pooling the observations across individual countries and time is the homogeneity of the regression coefficients. Usually, fixed effects (FE) and random effects (RE) are used in panel data model estimation. One of the desirable features of the FE design is that it allows for the unit specific effect to be correlated with other explanatory variables. Thus, it explicitly accounts for the form of endogeneity resulting from time-invariant omitted variables. Meanwhile, the RE model assumes that the unit-specific effect is uncorrelated with

explanatory variables. Fixed effects model could remove the effect of these time-invariant characteristics from the predictor variables, so the predictors' net effect could be easily assessed. Therefore, I develop fixed effects models to examine how wheat support in different countries evolves with income growth, and also test for random effects as noted below. The equation for the fixed effect model is as follows:

$$Y_{it} = \alpha_0 + \alpha_1 Inc_{it} + \alpha_2 Inc_{it}^2 + \alpha_3 Inc_{it}^3 + \sum \beta_k D_k + \gamma TS_{it} + \delta APR_{it} + \varphi PALA_{it} + \vartheta S_{it} + \sum_1^{n-1} \alpha_i + \varepsilon_{it} \quad (1),$$

where *Y* represents the indicators of wheat market distortions, namely *NRA*, *NRA_o*, *NRA_bms*, *NRA_dms*, or *NRA_i*; *Inc* represents real income per capita, constant 2000 USD; *D* is a dummy variable for food price crises, and *k* ranges from 1 to 3, representing world wheat price crises during 1973-74,1986-88, and 2006-08; *TS* indicates the trade status of country *i* in year *t*, which takes values of 1 if a net importer and 0 if a net exporter; *APR* represents agriculture population share; *PALA* is per capita arable land area; *S* represents the shift variable, which was equal to 1 for the developed countries since 1998 and for the developing countries since 2002, and equal to 0 for all countries in the other years; α_0 is a constant; α_i is the dummy variable for individual country (n-1 country-specific intercepts); *i* indicates individual countries from 1 to k; *t* indicates years from 1961 to 2011; and ε is the error term. Shift variable is a rough proxy for URAA or WTO accession, but does not correspond very well with the URAA implementation period.

Software STATA is used for all estimations and tests.

Hausman test is used to evaluate the presence of fixed effects or random effects to be included in the panel data model. The hypothesis for Hausman test (H_o) is that the difference in coefficients is not systematic. Denotation for the coefficients of fixed effects model is *b* and the coefficients of random effects model is *B*, the test statistic was

$$\textbf{chi2 = (b-B)'[(V\_b-V\_B)^(-1)](b-B)}.$$

If Prob (>chi2) < 0.05, as is the case in my experiments, I reject H_0, and use a fixed effects model.

The Wooldridge test for autocorrelation in panel data is applied in command *xtserial*. The null hypothesis of this test (H_0) is that there was no first-order autocorrelation, and the alternative hypothesis (H_1) is that the presence of first-order autocorrelation could not be rejected.

A potential risk for endogeneity exists because agricultural policy can affect the right-hand-side variables in the regression. While the objective remains to conduct a single regression with all countries included in the sample, I compare the regression results using different groups of countries within the sample to investigate the potential for endogeneity. With the inclusion of different groups of countries for each regression, the potential risk of endogeneity caused by income and trade status would be exhibited. First, for high income countries, agriculture GDP accounts for a very small part of the total GDP, so it seems reasonable to assume that modest changes in agricultural policy – and more specifically in wheat policy – would not bring about substantial changes to average income per capita in these countries. Starting with this assumption, I also compare regressions of all 55 wheat countries and only high income countries. If mostly consistent

results are found, then I would argue that the parameter estimates of the full sample do not appear to suffer from endogeneity bias due to this possible relationship. Second, I define (i) a group of wheat exporting countries and (ii) a group of wheat importing countries. I test these groups separately so I would not need the trade status variable for these two regressions. If the estimated results from these two groups are consistent with the regression with all 55 countries, it could be inferred that trade status might not cause an endogeneity problem with the agricultural policy.

In addition, three dummy variables are used to represent three wheat price shocks. This choice could also reduce the potential endogeneity problem. In contrast, Anderson and Nelgen (2012) use the percent deviation of international price from its trend, which explicitly represents the wheat price and is prone to the endogeneity issue of a variable that is intended to be independent. However, the price shock dummies used in this study are less likely to depend on NRA measures of any given year.

1.5 Empirical Results and Analysis

The results of Hausman tests shown in Table 1 are calculated based on the estimation of NRA using equation (1) with fixed effects and random effects. According to the results, I conclude that a fixed effect model is appropriate to estimate equation (1) for all wheat producing countries, high income countries, Asia developing countries, European transition and Mediterranean. However, for Latin American developing countries and Sub-Saharan African developing countries, I cannot reject $H_{0,}$ which means that random effect might be more suitable for Latin American developing panel and Sub-Saharan Africa panel.

As shown in Table 1, the autocorrelation test results of all panel groups are significant, and I can confidently reject the hypothesis that there is no first order autocorrelation. I use command *xtregar* in STATA to correct first order correlation in the panel data. *xtregar* fits a cross-sectional time-series regression model when the disturbance term is first order autoregressive. *xtregar* offers a within estimator for fixed-effects models.

$$\varepsilon_{it} = \rho\varepsilon_{i,t-1} + \tau_{it}$$

Where $|\rho| < 1$ and $\tau_{it}$is independent and identically distributed (i.i.d.) with mean 0 and constant variance.

Table 1 Results of Hausman test and autocorrelation test

Hausman Test			
Regions	**Chi2**	**P**	**Results**
All country	69.69	0.00	Reject H_0
High income countries	67.31	0.00	Reject H_0
EU high income countries	144.66	0.00	Reject H_0
Asia excl. Japan	54.41	0.00	Reject H_0
Latin America	8.4	0.21	Cannot reject H_0
European transition & Mediterranean	22.5	0.004	Reject H_0
Sub-Saharan Africa	4.21	0.76	Cannot reject H_0
Autocorrelation Test			
Regions	**F**	**P**	**Results**
All country	72.21	0.00	Reject H_0
High income countries	22.52	0.00	Reject H_0
Asia excl. Japan	16.79	0.01	Reject H_0
Major producing countries	32.50	0.00	Reject H_0
Major exporting countries	9.19	0.02	Reject H_0
Major importing Countries	14.21	0.01	Reject H_0

Source: estimated by the author.

Table 2 reports the estimation results of NRA with different specifications, and the preferred specification is selected by comparing the measures of fit. Equation (1) uses similar variables as Anderson and Nelgen (2012). However, it includes dummies for the world food spikes or slumps, a shift that approximates the URAA, as well as per capita

income cubed (GDP^3) since the optimal polynomial degree is 3 based on MSE, adjusted R square, AIC and F-test. Except agricultural population ratio (APR), all other variables in the equation (1) are statistically significant at the 5% level. Equation (2) is estimated using a country fixed effect model, which controls for unobservable and invariant factors over time for individual country, and the results indicate that per capita arable land area (PALA) is no longer significant, possibly because its influence might be included by country fixed effect. Equation (3) employs a linear fixed effect model with first order autoregression (AR) of disturbance. The values of adjusted R-square of equation (2) and (3) are smaller compared to OLS regression, but the signs of income terms reverse. In the results of equation (3), the coefficient of the AR (1) disturbance is around 0.64, indicating that NRA_t and NRA_{t-1} are highly related. When lagged NRA is added in equation (4), the results show that the coefficient of lagged NRA is statistically significant at the 1% level with the size of 0.62. F-tests show that per capita arable land and agricultural population rate are redundant variables. Thus, equation (5), which accounted for 68% of the variation in nominal rate of assistance to wheat in our sample, is the final selected specification. In equation (5), all the coefficients of dummies for food price crises are significant, which means that wheat support increased during the food price spikes and decreased during the food price slumps. Moreover, the coefficients of dummy for trade status are positive and statistically significant, which suggests that countries provide more protection to domestic producers if they import wheat.

Table 2 Regression results using different equation specifications of NRA based on all countries

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Lagged NRA				0.61	0.61
				(0.02)***	(0.02)***
Ln(Inc_lag)	3.62	-3.80	-1.36	-1.61	-1.58
	(0.69)***	(1.07)***	(0.45)***	(0.81)**	(0.80)**
Ln(Inc_lag)^2	-0.48	0.55	0.25	0.24	0.23
	(0.09)***	(0.14)***	(0.08)***	(0.11)**	(0.10)**
Ln(Inc_lag)^3	0.02	-0.02	-0.01	-0.01	-0.01
	(0.00)***	(0.01)***	(0.00)***	(0.00)***	(0.00)**
Dummy 1	-0.55	-0.50	-0.28	-0.29	-0.29
	(0.06)***	(0.05)***	(0.04)***	(0.04)***	(0.04)***
Dummy 2	0.43	0.41	0.36	0.23	0.23
	(0.05)***	(0.04)***	(0.04)***	(0.03)***	(0.03)***
Dummy 3	-0.10	-0.11	-0.08	-0.08	-0.08
	(0.04)**	(0.04)***	(0.03)***	(0.03)***	(0.03)***
Trade	0.41	0.24	0.12	0.09	0.09
	(0.03)***	(0.03)***	(0.04)***	(0.03)***	(0.03)***
PALA	-0.01	-0.00	-0.00	0.00	
	(0.00)***	(0.01)	(0.02)	(0.01)	
APR	-0.08	-0.18	-0.12	0.04	
	(0.13)	(0.22)	(0.40)	(0.18)	
Shift	-0.15	-0.21	-0.09	-0.07	-0.07
	(0.03)***	(0.03)***	(0.04)*	(0.02)***	(0.02)***
Constant	-9.25	7.53	1.51	3.03	3.01
	(1.78)***	(2.67)***	(0.34)***	(1.96)*	(1.96)
Adjusted R^2	0.33	0.18	0.15	0.65	0.65
Fixed Effect	No	Yes	Yes	Yes	Yes
AR(1)	No	No	Yes	Yes	Yes
			(0.64)	(0.04)	(0.04)
Obs	2077	2077	2022	2020	2020

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. Income per capita is dollars constant at 2000. Dummy 1-3 represents the year 1973-74, 1986-88. 2006-08, respectively; trade=1 for import, and trade=0 for export.

Table 3 shows the main results. This study treats NRA, NRA_o, NRA_bms, NRA_dms, and NRA_i as the major outcome variables, and estimates the outcome variables with a dynamic fixed effect model based on the data of 55 countries from 1961 to 2011. The second column of Table 3 reproduces the preferred regression for NRA. As discussed, all the coefficients are statistically significant at the 5% level, the results show how income and other factors drive overall support, and the regression explained 65% of the variation in NRA.

There are several important results from the estimates over the components of NRA. First, the results for NRA_o are mostly consistent with NRA, suggesting that most of overall NRA is focused on output. Second, the parameters of NRA_o are almost equal to the sum of those of NRA_bms and NRA_dms. As wheat output support is comprised of border market support and domestic market support, it is reassuring that the results are consistent for NRA_o and for these components estimated separately. Third, border market support is significantly affected by income, dummy for food crises and trade, while these factors have no significant effect on domestic market support. Fourth, input support or subsidies counted in NRA_i are not related to income based on the results in Table 3. Therefore, the results in Table 3 can lead one to conclude that in most countries income might have its greatest impact on how wheat policies intervene in the wheat market through its impact on border measures.

Estimated parameters imply non-linear effects of per capita income on wheat support that can be expressed in terms of the peaks and troughs of support (Table 4). Increases in income cause NRA to fall at very low levels of income, but then rise as income rises until, at some point, wheat support again begins to decrease. The fact that border measure support seems to hit that last turning point earlier than domestic output support or input subsidies corresponds to casual observations about the switch in developed countries to less coupled policies. Taking China and India as examples of developing countries, GDPs per capita are estimated to be 5,978 and 1,642 real dollars, respectively, in 2015, so they are still far from the income level for a local maximum, 23,425 dollars. These and other developing countries are expected to continue to increase support (such as price support,

fertilizer and seed subsidies) to wheat industry for some time to come, according to these estimates that are based on historical patterns.

Table 3 Regression results based on 55 wheat countries

Dependent Variables	**NRA**	**NRA_o**	**NRA_bms**	**NRA_dms**	**NRA_i**
Lagged Dependent Variable	0.61 (0.02)***	0.61 (0.02)***	0.59 (0.02)***	0.56 (0.02)***	0.74 (0.02)***
Ln(Inc_lag)	-1.58 (0.80)**	-1.60 (0.80)**	-1.36 (0.79)*	-0.26 (0.32)	-0.01 (0.05)
Ln(Inc_lag)^2	0.23 (0.10)**	0.24 (0.10)**	0.20 (0.10)**	0.04 (0.04)	0.00 (0.01)
Ln(Inc_lag)^3	-0.01 (0.00)**	-0.01 (0.00)**	-0.01 (0.00)**	-0.00 (0.00)	-0.00 (0.00)
Dummy 1	-0.29 (0.04)***	-0.30 (0.04)***	-0.28 (0.04)***	-0.03 (0.02)	0.00 (0.00)
Dummy 2	0.23 (0.03)***	0.23 (0.03)***	0.25 (0.03)***	-0.01 (0.02)	0.00 (0.00)
Dummy 3	-0.08 (0.03)***	-0.07 (0.03)**	-0.08 (0.03)***	0.01 (0.02)	-0.00 (0.00)
Trade	0.09 (0.03)***	0.09 (0.03)***	0.07 (0.03)***	0.02 (0.02)	0.00 (0.00)
Shift	-0.07 (0.02)***	-0.07 (0.02)***	-0.04 (0.02)*	-0.03 (0.01)**	-0.00 (0.00)**
Constant	3.01 (1.96)	3.11 (1.97)	2.60 (1.99)	0.32 (0.71)	0.02 (0.14)
Adjusted R^2	0.65	0.65	0.62	0.41	0.71
Fixed effect	Yes	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
Obs	2020	2020	2020	2020	2020

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. Income per capita is dollars constant at 2000. Dummy 1-3 represents the year 1973-74, 1986-88, 2006-2008, respectively; trade=1 for import, and trade=0 for export.
Source: estimated by authors.

Table 4 Real income levels associated with local minimums and maximums of different types of wheat support (dollars)

Dependent variables	Local minimum	Local Maximum
NRA	166	23425
NRA_o	179	21822
NRA_bms	181	14799
NRA_dms	119	280026
NRA_i	255	3.47E+13

Sources: calculated by the author.

Generally, it is not easy to imagine the curve of the function with cubic term. In order to give a better understanding about the nature of the relationship, the estimated NRA as a function of income is shown in Figure 2. The relationship between NRA and income per person is reasonable over the range of values tested here, varying around a fairly limited range of values and following a pattern that seems plausible.

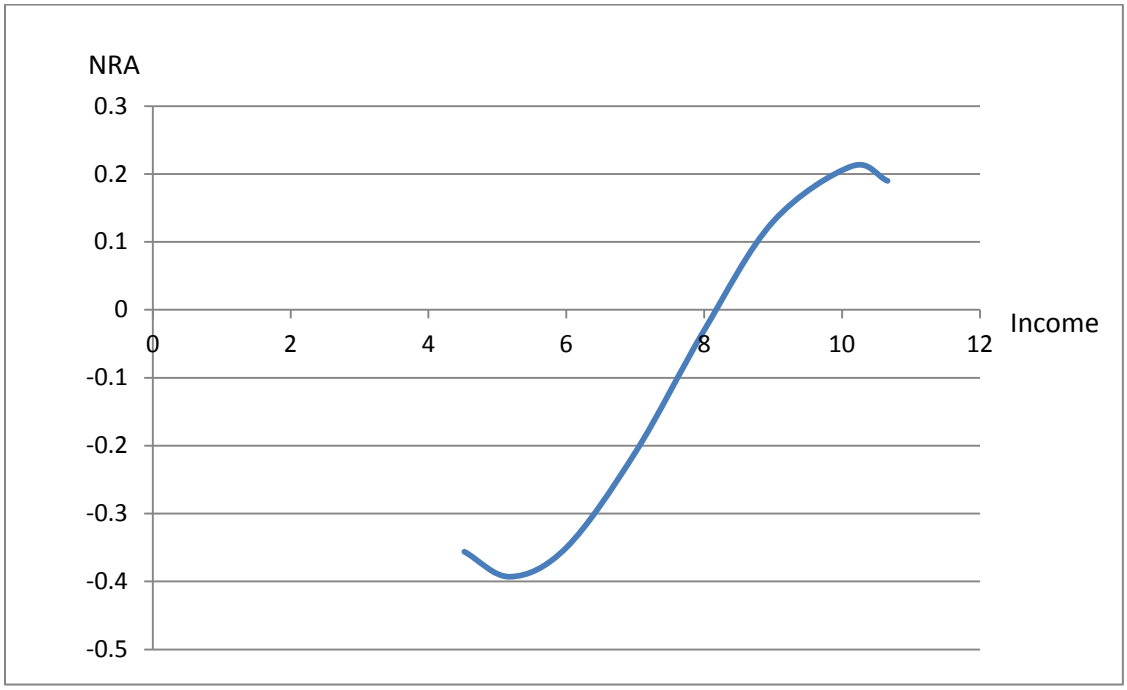

Figure 2 Relationship between NRA and Ln (income per person) (in 000 USD)

Source: simulated by the author.

The high income countries in the World Bank Agricultural Distortion Database include Australia, Austria, Belgium, Canada, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and the United States. This study estimates the causes of NRA and its components for this group of countries to

test the robustness of the primary results and to check for the potential endogeneity of income. The independent variables explain 74% of variation in nominal rate of assistance (NRA) to wheat in high income countries, which is higher than the 65% for all 55 wheat countries. The signs and significance of coefficients for high income countries in Table 5 are mostly consistent with the results in Table 3 for all 55 countries that include both developed and developing countries. We also have several additional findings from the results based on high income countries. First, income has a significant effect on NRA to wheat, but no significant effect on either border market support or domestic market support. Second, during the 1973-74, 1986-88, and 2006-08 food crises, high income countries took significant border market measures. Third, high income wheat importing countries also support wheat price, and typically use border market measures to do so.

This study also tests the causes of NRA for China, India, Korea, Pakistan, and Bangladesh, a group of countries that represent Asian developing countries. As shown in Table 6, the regression has higher explanatory power, around 84% of variations in NRA, and several conclusions are drawn based on these results. First, income has statistically significant effects on both border market support and domestic market support. Second, when these Asian countries import wheat, producers are supported by domestic policy measures. Third, the world food price slump in 1986-88 had a significantly positive effect on border market support and negative effect on domestic market support. Comparing high income countries and Asian developing countries, income has a statistically significant effect on domestic market support in Asian developing countries, but no statistically significant effect in the high income countries. Finally, the results of Asian

developing countries are very close to the results of 55 countries, which demonstrated the robustness of main results in Table 3.

Table 5 Regression results based on 21 high income countries

Dependent Variables	**NRA**	**NRA_o**	**NRA_bms**	**NRA_dms**
Lagged Dependent Variable	0.58 (0.02)***	0.58 (0.02)***	0.56 (0.02)***	0.55 (0.03)***
Ln(Inc_lag)	-25.42 (13.95)*	-25.42 (13.95)*	-14.27 (12.35)	-10.76 (10.41)
Ln(Inc_lag)^2	2.69 (1.49)*	2.69 (1.49)*	1.49 (1.32)	1.15 (1.11)
Ln(Inc_lag)^3	-0.10 (0.05)*	-0.10 (0.05)*	-0.05 (0.05)	-0.04 (0.04)
Dummy 1	-0.31 (0.06)***	-0.31 (0.06)***	-0.28 (0.05)***	-0.04 (0.04)
Dummy 2	0.38 (0.05)***	0.38 (0.05)***	0.40 (0.04)***	-0.01 (0.03)
Dummy 3	-0.09 (0.05)*	-0.09 (0.05)*	-0.12 (0.04)***	0.03 (0.04)
Trade	0.14 (0.05)***	0.14 (0.05)***	0.12 (0.04)***	0.03 (0.03)
Shift	-0.08 (0.05)*	-0.08 (0.05)*	-0.04 (0.04)	-0.05 (0.03)
Constant	79.61 (39.77)**	79.61 (39.77)**	45.40 (36.89)	25.74 (28.36)
Fixed Effect	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes
R^2	0.74	0.74	0.68	0.56
Obs	972	972	972	972

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. GDP per capita is dollars constant at 2000. Dummy 1-3 represents the year 1973-74, 1986-88, and 2006-2008, respectively. Because there is no input subsidies or support in high income countries, there is no column for NRA_i in the above table.
Source: estimated by authors.

Table 6 Regression results based on 5 Asia countries

Dependent Variables	**NRA**	**NRA_o**	**NRA_bms**	**NRA_dms**	**NRA_i**
Lagged Dependent Variable	0.57 (0.05)***	0.57 (0.05)***	0.62 (0.05)***	0.46 (0.06)***	0.71 (0.06)***
Ln(Inc_lag)	-8.32 (2.38)***	-9.77 (2.45)***	-6.72 (2.29)***	-3.00 (1.09)***	0.88 (0.56)
Ln(Inc_lag)^2	1.16 (0.34)***	1.36 (0.35)***	0.94 (0.32)***	0.42 (0.15)***	-0.12 (0.08)
Ln(Inc_lag)^3	-0.05 (0.02)***	-0.06 (0.02)***	-0.04 (0.01)***	-0.02 (0.01)**	0.01 (0.00)
Dummy 1	-0.40 (0.09)***	-0.41 (0.09)***	-0.36 (0.09)***	-0.05 (0.04)	0.03 (0.02)
Dummy 2	0.11 (0.06)*	0.11 (0.06)*	0.16 (0.06)***	-0.06 (0.03)**	0.00 (0.01)
Dummy 3	-0.13 (0.08)	-0.10 (0.08)	-0.10 (0.07)	-0.00 (0.03)	-0.01 (0.02)
Trade	0.14 (0.08)*	0.17 (0.08)**	0.11 (0.08)	0.07 (0.04)*	-0.01 (0.02)
Shift	-0.04 (0.06)	-0.02 (0.06)	-0.00 (0.06)	-0.01 (0.03)	-0.02 (0.01)*
Constant	18.95 (5.42)***	22.40 (5.57)***	14.55 (5.14)***	6.80 (2.50)***	-1.62 (0112)
R^2	0.84	0.85	0.82	0.63	0.77
Fixed effect	Yes	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
Obs	196	196	196	196	196

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. GDP per capita is dollars constant at 2000. Dummy 1-4 represents the year 1973-74, 2006-08, and 1986-88, respectively.
Source: estimated by authors.

To examine the causes of support for wheat exporting countries, this study reports the results for Australia, US and Canada in Table 7. For major exporting countries, income has no statistically significant effect on either border market support or domestic market support. In addition, the price spike in 1972-74 had statically significant and negative effect on nominal rate of assistance to wheat support in the exporting country, especially by border market measures. However, the food price slump in 1986-88 and price spike in 2006-08 had no statistically significant effect on nominal rate of assistance to wheat in

the exporting countries. These results might reflect the shift from coupled policies to decoupled policies in these exporting countries.

Table 7 Regression results based on major exporting countries (US, Canada, Australia)

Dependent Variables	**NRA**	**NRA_o**	**NRA_bms**	**NRA_dms**
Lagged Dependent Variable	0.47 (0.08)***	0.47 (0.08)***	0.33 (0.08)***	0.26 (0.08)***
Ln(Inc_lag)	-37.69 (30.05)	-37.69 (30.05)	-42.10 (31.00)	-12.15 (13.61)
Ln(Inc_lag)^2	3.89 (3.04)	3.89 (3.04)	4.35 (3.14)	1.22 (1.38)
Ln(Inc_lag)^3	-0.08 (0.03)	-0.08 (0.03)	-0.15 (0.11)	-0.04 (0.05)
Dummy 1	-0.08 (0.03)***	-0.08 (0.03)***	-0.08 (0.03)***	0.00 (0.01)
Dummy 2	0.03 (0.02)	0.03 (0.02)	0.01 (0.02)	0.05 (0.01)***
Dummy 3	-0.00 (0.02)	-0.00 (0.02)	0.01 (0.02)	-0.01 (0.01)
Shift	-0.01 (0.02)	-0.01 (0.02)	0.02 (0.02)	-0.01 (0.01)
Constant	121.80 (95.08)**	121.80 (95.08)**	111.70 (91.96)	40.27 (34.66)
R^2	0.46	0.46	0.33	0.41
Fixed effect	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes
Obs	147	147	147	147

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. GDP per capita is dollars constant at 2000. Dummy 1-3 represents the year 1973-74, 1986-88, and 2006-2008, respectively.
Source: estimated by authors.

Major wheat importing countries, namely Egypt, Brazil, Japan, Mexico, Chile, Colombia, and Bangladesh, are also examined separately. The results in Table 8 lead to several observations. First of all, income has a statistically significant effect on total nominal assistance to wheat, both in terms of border measures and domestic market support measures. Second, the price spikes in 1973-74 and 2006-08 had a statistically significant effect on border market support measures and minor effect on domestic market support.

Third, during the 1986-88 food price slump wheat producers were protected by border market support, but harmed by domestic market support in these major wheat importing countries. Fourth, income also has a statistically significant effect on wheat input assistance.

Comparing the results of Table 7 and Table 8, I note several differences. First, income might have larger and more statistically significant effect on wheat NRA in the major importing countries as compared to the effects on support provided by exporting countries. Second, world wheat price spikes affect agricultural support in the major importing countries more than agricultural support in major exporting countries. Third, wheat importing countries intervene in wheat market more than exporting countries.

Table 8 Regression results based on major importing countries

Dependent Variables	**NRA**	**NRA_o**	**NRA_bms**	**NRA_dms**	**NRA_i**
Lagged Dependent Variable	0.42 (0.06)***	0.42 (0.06)***	0.34 (0.06)***	0.17 (0.06)***	0.43 (0.06)***
Ln(Inc_lag)	12.91 (4.69)***	13.44 (3.94)***	10.84 (4.23)**	6.03 (2.69)**	-0.66 (0.33)**
Ln(Inc_lag)^2	-1.60 (0.57)***	-1.66 (0.57)***	-1.29 (0.51)**	-0.81 (0.33)**	0.08 (0.04)**
Ln(Inc_lag)^3	0.07 (0.02)***	0.07 (0.02)***	0.05 (0.02)**	0.04 (0.01)***	-0.00 (0.00)**
Dummy 1	-0.47 (0.13)***	-0.48 (0.13)***	-0.38 (0.12)***	-0.13 (0.08)	0.01 (0.02)
Dummy 2	0.12 (0.10)	0.11 (0.10)	0.26 (0.10)***	-0.13 (0.06)**	0.02 (0.01)**
Dummy 3	-0.15 (0.11)	-0.15 (0.11)**	-0.24 (0.11)**	0.12 (0.07)	-0.00 (0.01)
Shift	-0.13 (0.09)	-0.13 (0.09)	-0.08 (0.08)	0.07 (0.05)	-0.00 (0.01)
Constant	-34.71 (11.65)***	-36.05 (11.73)***	-33.67 (9.72)***	-14.75 (7.28)**	1.36 (0.79)*
Fixed effect	Yes	Yes	Yes	Yes	Yes
AR(1)	Yes	Yes	Yes	Yes	Yes
R^2	0.67	0.67	0.41	0.58	0.25
Obs	268	268	268	268	268

Note: ***denotes significance at the 1% level, **denotes significance at the 5% level, * denotes significance at 10% level. GDP per capita is dollars constant at 2000. Dummy 1-3 represents the year 1973-74, 1986-88, and 2006-2008, respectively.
Source: estimated by authors.

Before turning to some of the implications of these estimates, consider several points regarding the possibility of endogeneity problems in our model. First, because agriculture income is a small share of total GDP in high income countries, it should be reasonable to assume that the causal relationship could be from income to agricultural support in these countries, but not the other way around. The results indicate that the effects of income are consistent for all 55 wheat countries (Table 3) and for the sub-sample of high income wheat countries (Table 5). Although these results are not identical, the high degree of similarity leads to the conclusion that endogeneity caused by the possible effects of wheat policy on income growth is not a concern in our model. Second, I limit the endogeneity

caused by the link between international wheat price and NRA by using dummies for the international wheat price crises instead of using the price directly. As regards these two possible sources of endogeneity bias, therefore, the model is less likely to have serious problems. The case is not as strong for the trade status dummy, however, as differences between major wheat exporting and importing countries are somewhat more pronounced. Although the broad outlines of the role of income and other causal factors are fairly similar for these two sub-samples, I nevertheless recognize that this represents a potential concern.

1.6 Wheat Support Projection

Wheat support is projected until 2025 for a selection of countries, focusing on China and the US. These projections use estimated parameters from Table 3, on the assumption that these are the broadest set of results and most likely to represent correctly the relationships over changing conditions of the future. The estimates are developed by, first, calibrating the model to the last historical observation, and then projecting forward from that point. The income growth assumptions for different countries are based on World Bank and OECD forecasts, as shown in Table 9 and Table 10.

Table 9 GDP growth forecast, constant 2010 USD by World Bank

Location	2011	2012	2013	2014	2015	2016	2017
China	9.3	7.7	7.7	7.4	7.1	7.0	6.9
India	6.6	4.7	5.0	5.6	6.4	7.0	7.0
United States	1.6	2.3	2.2	2.4	3.2	3.0	2.4
High Income Countries	1.9	1.4	1.4	1.8	2.2	2.4	2.2
OECD countries	1.8	1.3	1.4	1.7	2.2	2.4	2.2
High income: OECD	1.6	1.2	1.3	1.7	2.3	2.4	2.1

Source: www.worldbank.org/en/publication/global-economic-prospects/data

Table 10 Real GDP forecast, Total, Annual growth rate (%) by OECD

Location	2011	2012	2013	2014	2015	2016
Australia	2.6	3.7	2.0	2.7	2.3	2.9
Canada	3.0	1.9	2.0	2.4	1.5	2.3
China (People's Republic of)	9.5	7.7	7.7	7.4	6.8	6.7
France	2.1	0.2	0.7	0.2	1.1	1.7
India	7.7	5.2	6.4	7.2	6.9	7.6
Japan	-0.5	1.7	1.6	-0.1	0.7	1.4
Korea	3.7	2.3	2.9	3.3	3.0	3.6
Norway	1.0	2.7	0.7	2.2	1.2	1.5
OECD – Total	1.9	1.3	1.4	1.8	1.9	2.5
Switzerland	1.8	1.1	1.9	2.0	0.8	1.7
United Kingdom	1.6	0.7	1.7	2.8	2.4	2.3
United States	1.6	2.3	2.2	2.4	2.0	2.8
World	4.2	3.3	3.3	3.3	3.1	3.8

Source: data.oecd.org/gdp/real-gdp-forecast.htm

Figure 3 shows the prediction of wheat support in major wheat producing countries. By comparing the nominal assistance to agriculture (NRA) to wheat in the major wheat countries, the simulation results indicate that the wheat support in Japan would be the highest among these countries. According to these results, wheat support in China and India show the largest increases in the future. Developed countries, like Canada, US, Australia, France, change wheat support very little.

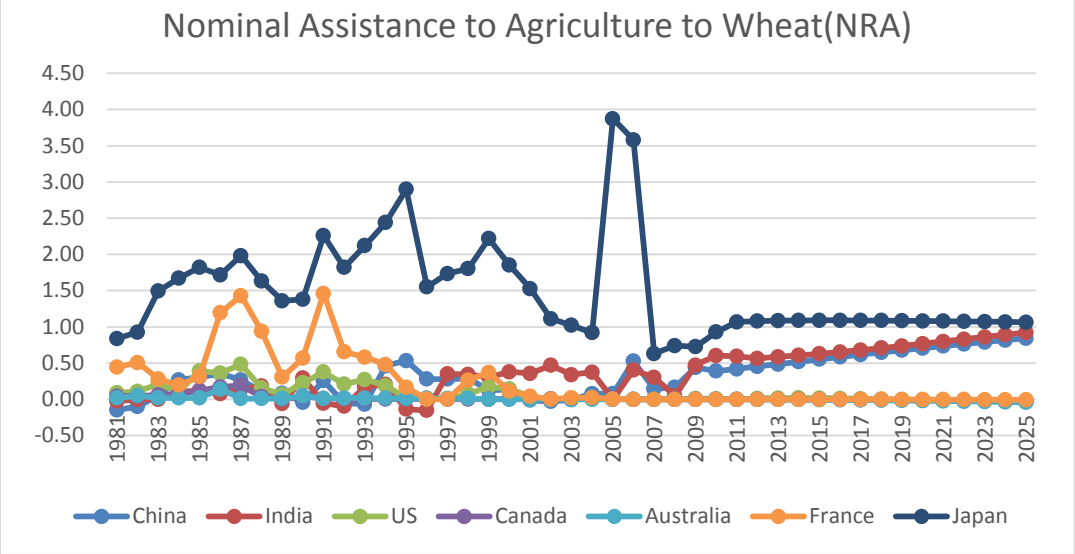

Figure 3 Projecting wheat support in selected Countries until 2025

Source: simulated by the author.

China is the biggest producing and consuming country of wheat in the world. Here, I emphasize the projection of wheat support in China under different scenarios. In the baseline, I assume China's per capita Gross Domestic Products (GDP) increases by 7% each year from 2015 on. If there is no international price crisis, the future wheat support in China predicted by our model increases quickly in the coming years (Figure 4). The wheat support mainly depends on border market measures in these estimates, with market support explaining around 80% of the total. Domestic market support slightly increases as well. In contrast, support to inputs remains modest in the projection period.

The projections can be extended with and without the effect of the shift variable that is intended to represent the URAA or, in the case of China, WTO accession (Figure 5). If this shift variable is set to zero, rather than a value of one, then the projected future wheat support in China is 13%-22% higher. In Figure 6, I project the future wheat support under different assumptions for GDP growth rate since 2015 in China, which reflects the range of projected support under different income growth rates (5%~9%) in China.

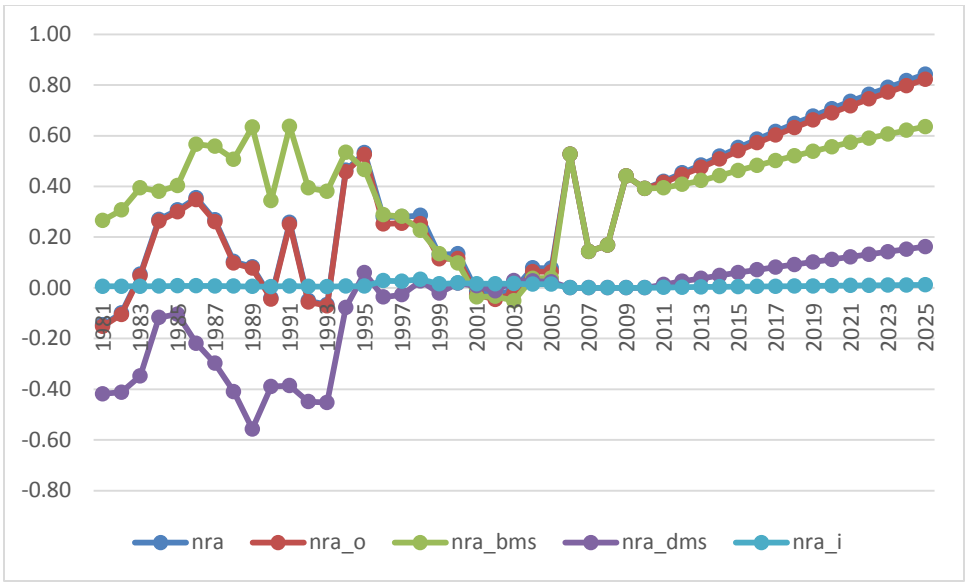

Figure 4 Projecting wheat support in China until 2025 (Baseline)
Source: simulated by the author.

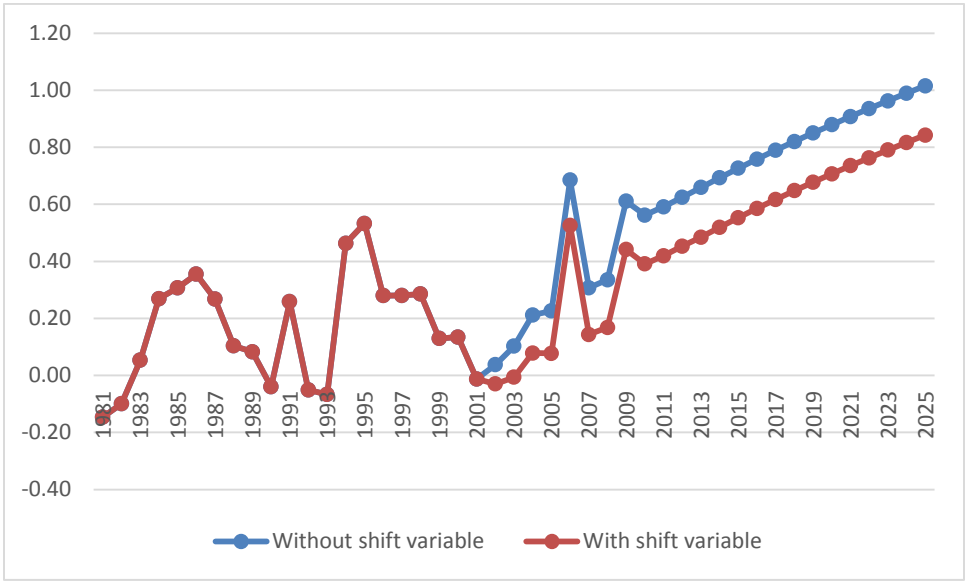

Figure 5 Wheat support projection in China with and without shift variable
Source: simulated by the author.

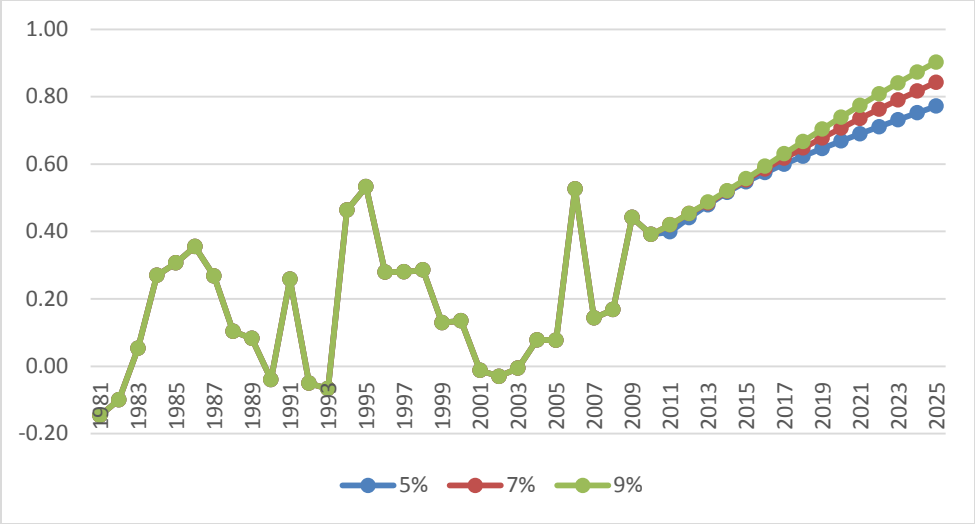

Figure 6 Wheat support projection in China with different income growth rates
Source: simulated by the author.

The US offers an example of the future wheat support trends in the developed countries based on these estimates. The historical and projected values of wheat support in US are indicated in Figure 7. The domestic market support for wheat in the US increases slightly, according to these estimates, while the nominal rate of assistance to wheat by border measures is estimated to be slightly negative in the future.

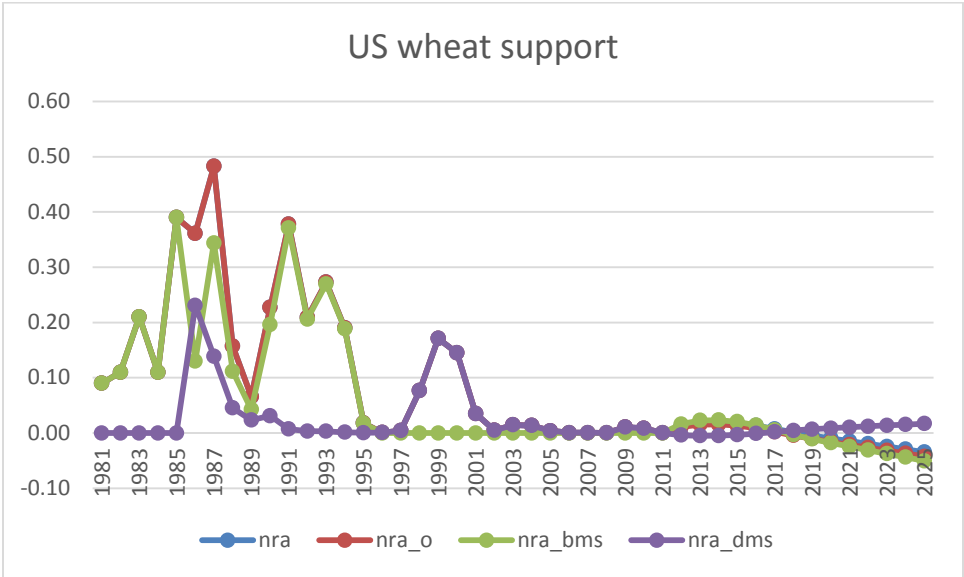

Figure 7 Projecting wheat support in the US until 2025
Source: simulated by the author.

The sensitivity of these projections to uncertainty in estimation, policy environment, and GDP assumptions can be explored. Taking China and US, for example, Figure 8 reports the projecting wheat support in China and US with 95% confidence interval. These data are developed from the confidence interval of residual, estimated using bootstrapping.

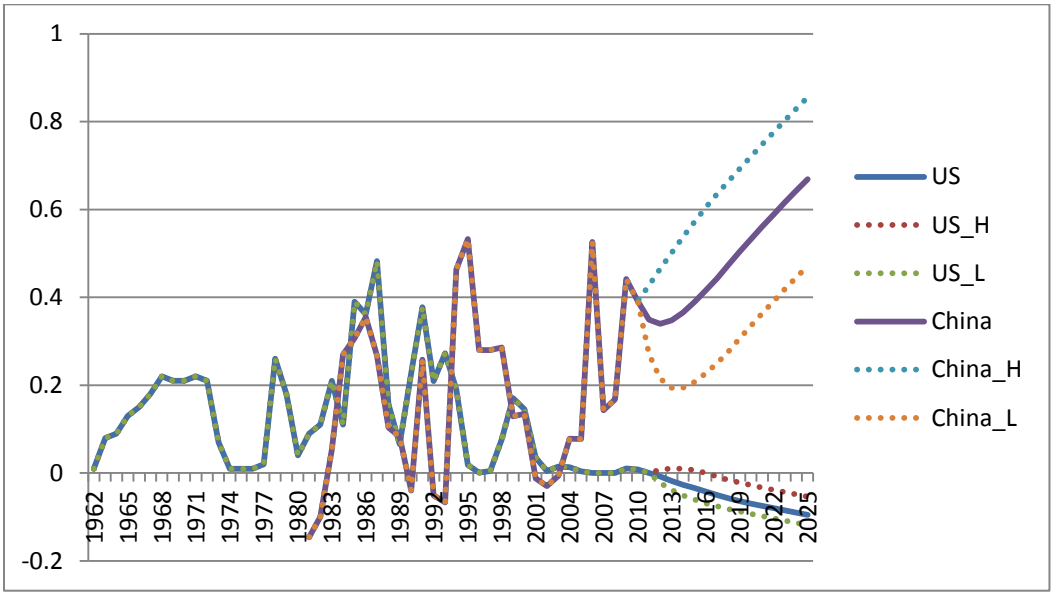

Figure 8 Projection of NRA in China and US with confidence intervals

Notes: H is upper value, and L is lower value.
Source: estimated by the author.

Projected NRA can be set in a broader context by comparing them to historical NRA, taking per capita income into account (Table 11). For example, the average income levels in 2021-25 in China and India would still be far below the income levels of the developed countries in 1981-85. Thus, it is perhaps unsurprising that the projected NRA of China and India are higher than some developed countries' NRA in that historical period and lower than others. One outcome of this comparison is that the extrapolation of income is unlikely to be a serious issue: even with the assumption of strong growth in China and India, income per person in these countries remains well within the ranges of historical

data. As regards extrapolating incomes and support in richer countries, the projected levels stretches the upper end of the income range to a limited extent and does so without causing much change in support.

Table 11 Historical data and projection for real income (000 USD per capita) and NRA

Country		1981-85	1991-95	2001-05	2011-15	2021-25
China	**GDP**	0.2	0.5	1.2	3.1	6.0
	NRA	0.08	0.23	0.02	0.49	0.79
US	**GDP**	24	29	36	40	49
	NRA	0.18	0.21	0.01	0.01	-0.02
Canada	**GDP**	17	19	25	27	33
	NRA	0.07	0.01	0.01	0.00	-0.02
France	**GDP**	16	20	23	24	27
	NRA	0.35	0.67	0.02	0.00	0.00
Japan	**GDP**	26	35	38	39	43
	NRA	1.35	2.31	1.69	1.08	1.07
Australia	**GDP**	15	17	22	28	37
	NRA	0.03	0.01	0.00	0.00	-0.03
India	**GDP**	0.3	0.3	0.5	1.0	1.9
	NRA	0.04	0.02	0.31	0.60	0.86
Switzerland	**GDP**	29	32	34	39	46
	NRA	2.30	2.69	0.60	0.20	0.17
Norway	**GDP**	24	29	38	42	48
	NRA	2.43	2.45	1.34	0.38	0.21

Sourced: Calculated and estimated by the author.

1.7 Discussion and conclusions

My findings focus on how income growth affected wheat policy. Wheat is different from other crops: first, more area is planted for wheat than any other crops; second, world trade in wheat is greater than any other crops, and major exporting countries are all developed countries; and third, wheat price has been more volatile since 2000. Anderson et al. (2010) explain agricultural distortion patterns of national average assistance level. However, wheat support varies among countries. Anderson and Nelgen (2012) attempt to explain the variation in the nominal assistance to wheat with an OLS regression based on data representing all countries in their sample.

This comparison raises the broader question of how the regression results presented here compare to previous work. Anderson et al. (2010) and Anderson and Nelgen (2012) successfully explain the patterns of agricultural distortions, and indicate that income mattered in the evolution of agricultural policy. With their research as foundations, my study adds value to literatures in the evolution of wheat policy as well as its future trend. Several aspects of my research are distinct from these studies: first, I use country fixed effect estimation validated by the Hausman tests; second, I include a group of dependent variables to differentiate wheat policy based on whether it targeted trade, domestic policies, border measures, or inputs; and third and perhaps most importantly, this study projects future support based on the results.

This study also has some limitations. First, due to the technical restriction in panel data analysis, while the tests and corrections for first order serial correlation within individual countries represent an improvement, autocorrelation of higher orders might still exist. Second, the results are shown to be robust with respect to certain factors by comparing overall results with subgroup results, but these experiments also highlight some areas where further research could be useful to identify different subgroup behaviors or to account for the potential endogeneity of certain variables. In addition, while these results confirm that income growth affects policies, the focus could be excessively focused on relatively short- or medium-run linkages, admittedly with lagged dependent variables that can account for partial adjustment. Policies in countries last for several years, however, and efforts to merge research on direct estimation, in which this study played a part, and the literature on political economics could hold promise. Another area for future study is to test other measures of the market distortion of agricultural policy, as well as testing

other commodities or for agriculture in aggregate. In addition, this study has not linked the projected support level to wheat production.

Table 12 Comparison between this study and Anderson et al. (2009, 2012)

	Our paper	Anderson, Nelgen	Differences
Dependent variable	NRA, NRA_o, NRA_i, NRA_bms, NRA_dms	NRA	This study uses the estimation of components to support the validation of NRA, NRA_o.
Explanatory variables			
GDP, first and higher orders	Yes	Yes	Both find that income matters in agricultural support, but I find that income cubed is also significant.
Arable land area per capita	Yes	Yes	Tested in the present study, but it has no significant effect.
Agricultural population ratio	Yes	No	Tested in the present study, but it has no significant effect.
Dummies for food crises	Yes	No	These terms might avoid the simultaneity with NRA as compared to price deviation.
Deviation of international price from its trend	No	Yes	This term might cause a simultaneity problem with NRA.
Dummy for trade	Yes	Yes	
Estimation			
Fixed effect	Yes	No	Validated in this study with the fixed effect model using Hausman tests.
Different groups	Yes	No	Separated countries in this study by income, region, and trade status to verify robustness of the model.
Serial correlation correction	Yes	No	Corrected the first order serial correlation in this study.

In summary, I emphasize the following findings.

First, I find that income has a significant effect on agricultural support for all 55 wheat countries, which is consistent with Anderson et al. (2010) and Anderson and Nelgen (2012). However, this study demonstrates that wheat support has a statistically significant relationship with income, income square and income cubed. The effects of rising income on the support are more complicated than earlier research suggests. Moreover, based on the decomposition of wheat policy exploited here, the results here show that income has a statistically significant effect on border market support while it had no statistically significant effect on domestic market support. For our subgroups, income has a statistically significant effect on wheat support in high income countries, Asian developing countries, and major importing countries.

Second, the results reveal a possible relationship between wheat price spikes or slumps and support. During the wheat price spike periods, examined countries were more likely to use border support measures to intervene in the wheat market. When world wheat price was high in 1973-74 and 2006-08, these countries tended to tax or restrict their exports and subsidize their imports. When world wheat price was quite low in 1986-88, they tended to subsidize wheat exports and tax imports.

Third, tests of the effect of trade status on wheat support suggested that exporters and importers policies are systematically different. Countries that import wheat tend to provide more support wheat by border market measures and domestic policies than countries that export wheat. Furthermore, given the estimated effect of the shift variable which serves as a rough proxy for URAA or WTO accession, the results indicate that wheat support is lower after URAA or WTO accession.

Fourth, the time-invariant factors of individual countries, like natural resources, political system, might have a statistically significant effect on wheat support. For instance, with relatively low land area per capita, Japan protects its wheat industry at a very high level. Meanwhile, with rich land resources, the US, Canada, and Australia support their wheat industry at a relatively low level.

Finally, this study predicts future wheat support in several key countries. Japan is projected to maintain a high level of wheat support while China and India might continue to increase wheat support. China might increase wheat support using mostly border measures, as well as domestic measures. The US is projected to support the wheat producers at roughly unchanged, low levels mainly using domestic market support. To sum up, the developing countries may continue increasing their wheat support while the developed countries might change wheat support very little in the near future.

APPENDIX

Wheat distortions in high income countries

Some high income countries, like Japan, Norway, Switzerland, and New Zealand, have been wheat importing countries. Japan used both border market support and domestic market support to protect wheat industry before the year 2006. Especially, in 2005, the gross return of Japan's wheat producers is 3.87 times higher compared to the estimate based on world price without subsidies. The subsidies were at least partly implemented through an import tax. However, since 2007, Japan only took domestic measures to support wheat production and wheat farmers' gross return was still much higher compared to the estimate evaluated at world prices. Norway and Switzerland also adopted border measures to protect domestic wheat production and the protection level showed a downward trend in the past years.

The US, Canada, Australia, and France have been the major wheat exporting countries. The US, Canada, and Australia exerted little protection to their domestic wheat market compared to other high income countries of this study. The US had minor subsidies to wheat exports from 1962 to 1995, and provided some domestic support to wheat since 1986. Canada also had very low export subsidies to wheat before the year 1994 and very minor domestic support during the year 1986-2005. In addition, Australia applied some border measures to protect wheat production before the year 2000.

Figure A-3 indicated the main differences among EU countries based on trade status. For instance, Austria, Germany, Netherlands, and UK tended not to intervene in wheat market since they became wheat exporting countries from the year 1996. However, before 1996, they often used border market support to protect their wheat industry,

combined with domestic support measures for some years. By way of preview, the variable for trade status, which is used in estimation later, is defined as trade status=1 if it was imported in certain year, otherwise 0.

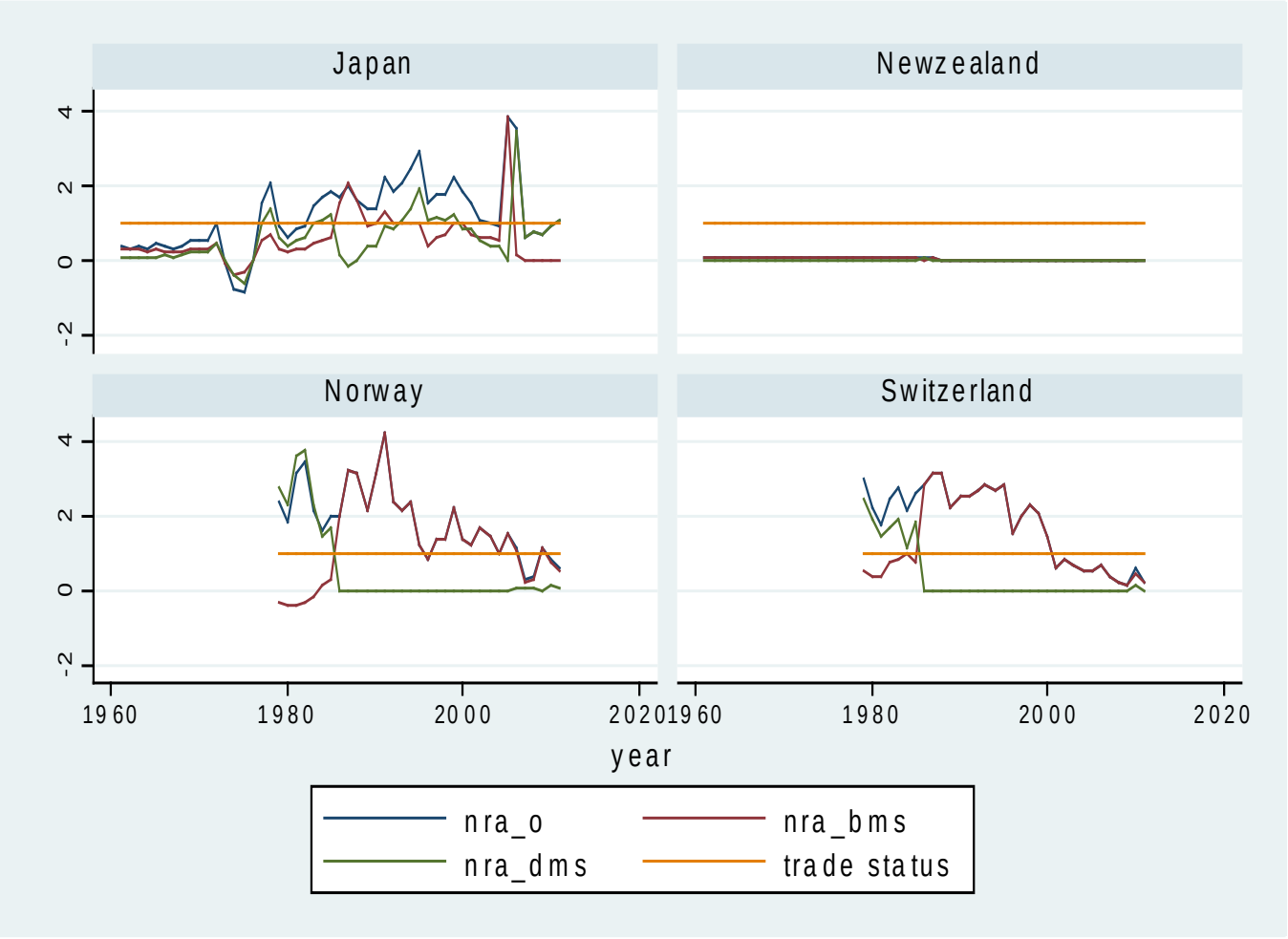

Figure A-1 Wheat support and Trade Status in High Income Countries

Note: trade status=1 if the country imports wheat in certain year, otherwise 0.

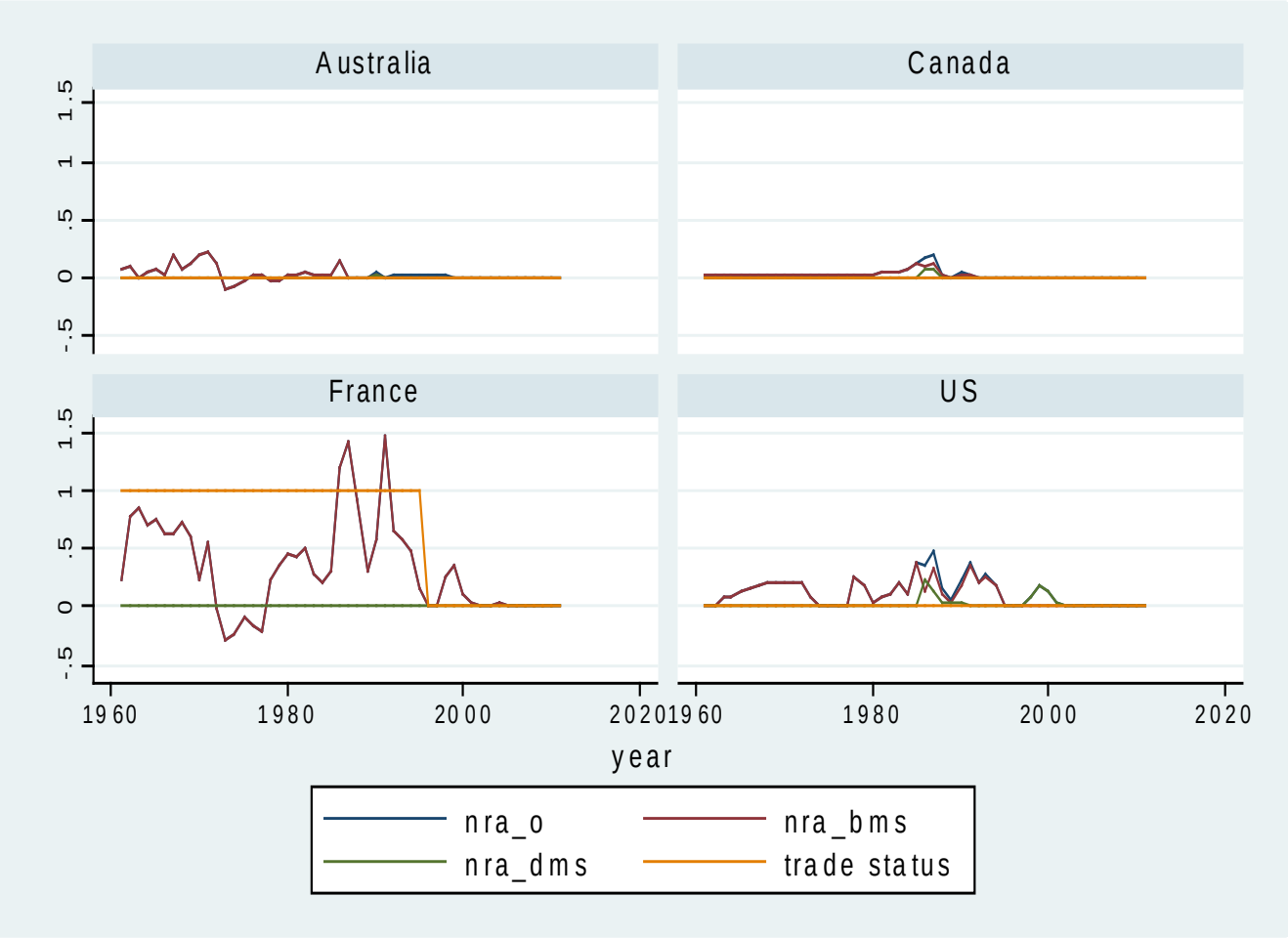

Figure A-2 Wheat support and trade status in high income countries

Note: trade status=1 if the country imports wheat in certain year, otherwise 0.

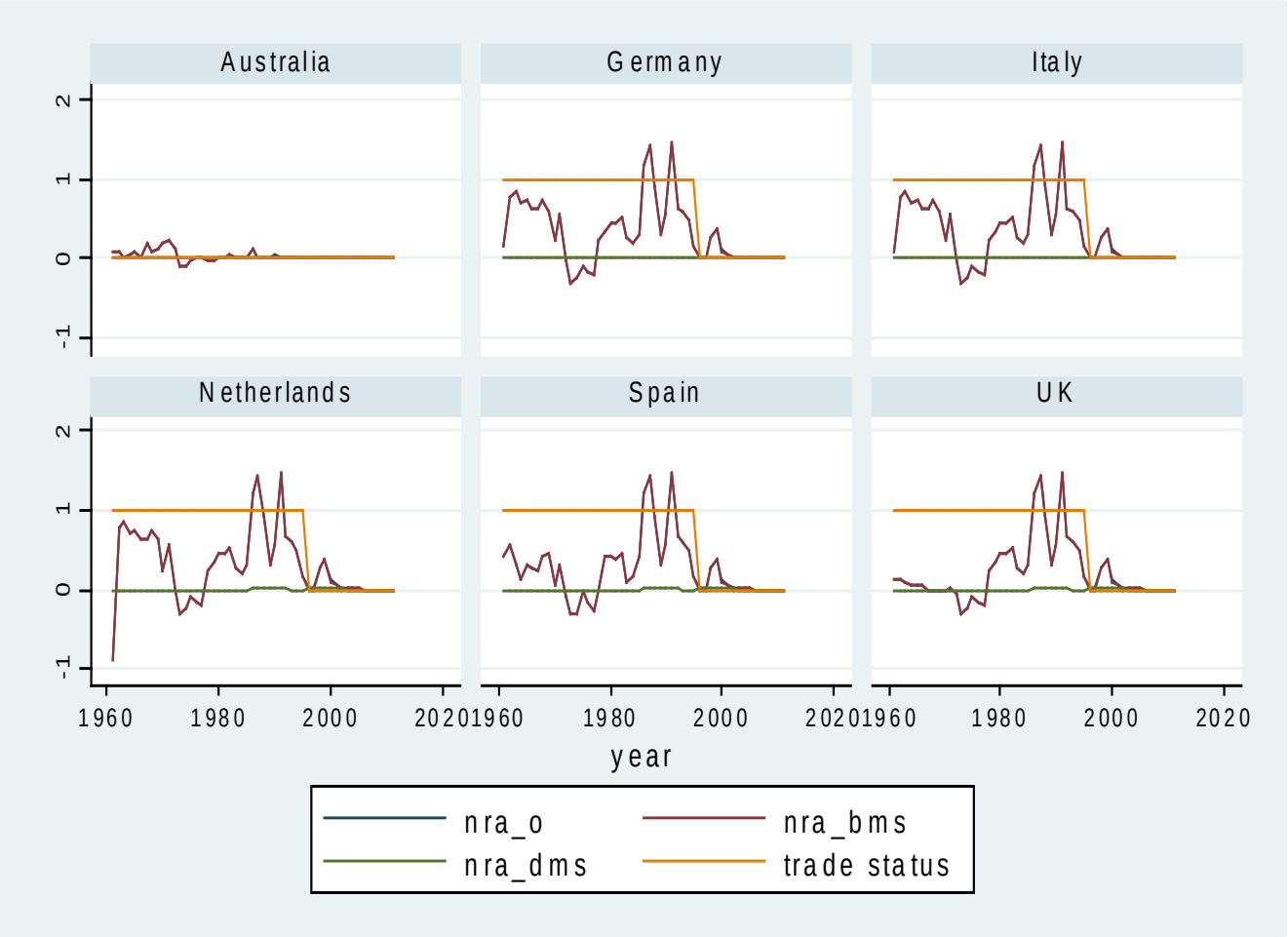

Figure A-3 Wheat support and trade status in high income countries

Note: trade status=1 if the country imports wheat in certain year, otherwise 0.

REFERENCES

Abbott, Philip C, and Linda M Young. 1999. "Wheat-Importing State Trading Enterprises: Impacts on the World Wheat Market." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 47 (2):119-136.

Alaouze, Chris M, AS Watson, and NH Sturgess. 1978. "Oligopoly pricing in the world wheat market." *American Journal of Agricultural Economics* 60 (2):173-185.

Anderson, Kym. 1995. "Lobbying incentives and the pattern of protection in rich and poor countries." *Economic Development and Cultural Change*:401-423.

Anderson, Kym, Johanna Croser, Damiano Sandri, and Ernesto Valenzuela. 2010. "Agricultural distortion patterns since the 1950s: what needs explaining?" *The political economy of agricultural price distortions.*

Anderson, Kym, Marianne Kurzweil, Will Martin, Damiano Sandri, and Ernesto Valenzuela. 2008. "Measuring distortions to agricultural incentives, revisited." *World Trade Review* 7 (04):675-704.

Anderson, Kym, and Signe Nelgen. 2012. "Trade barrier volatility and agricultural price stabilization." *World Development* 40 (1):36-48.

Baek, Jungho, and Won W Koo. 2006. "Price dynamics in the north American wheat market." *Agricultural and Resource Economics Review* 35 (2):265.

Bale, Malcolm D, and Ernst Lutz. 1981. "Price distortions in agriculture and their effects: An international comparison." *American Journal of Agricultural Economics* 63 (1):8-22.

Barassi, MR, and Atanu Ghoshray. 2007. "Structural change and long-run relationships between US and EU wheat export prices." *Journal of Agricultural Economics* 58 (1):76-90.

Carter, Colin, and Andrew Schmitz. 1979. "Import tariffs and price formation in the world wheat market." *American Journal of Agricultural Economics* 61 (3):517-522.

Demeke, Mulat, Guendalina Pangrazio, and Materne Maetz. 2008. "Country responses to the food security crisis: Nature and preliminary implications of the policies pursued." *Agricultural Policy Support Service, FAO*.

Ghoshray, Atanu. 2002. "Asymmetric price adjustment and the world wheat market." *Journal of Agricultural Economics* 53 (2):299-317.

Gómez-Plana, Antonio G., and Stephen Devadoss. 2004. "A spatial equilibrium analysis of trade policy reforms on the world wheat market." *Applied Economics* 36 (15):1643-1648.

Headey, Derek. 2011. "Rethinking the global food crisis: The role of trade shocks." *Food Policy* 36 (2):136-146.

Larue, Bruno, and Harvey E Lapan. 1992. "Market structure, quality and world wheat market." *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie* 40 (2):311-328.

McCalla, Alex F. 1966. "A duopoly model of world wheat pricing." *Journal of Farm Economics* 48 (3 Part I):711-727.

Oehmke, James F, and Xianbin Yao. 1990. "A policy preference function for government intervention in the US wheat market." *American Journal of Agricultural Economics* 72 (3):631-640.

Paarlberg, Philip L, and Philip C Abbott. 1986. "Oligopolistic behavior by public agencies in international trade: the world wheat market." *American Journal of Agricultural Economics* 68 (3):528-542.

Peterson, Willis L. 1979. "International farm prices and the social cost of cheap food policies." *American Journal of Agricultural Economics* 61 (1):12-21.

Sekhar, CSC. 2003. "Price formation in world wheat markets—implications for policy." *Journal of Policy modeling* 25 (1):85-106.

Shei, Shun-Yi, and Robert L Thompson. 1977. "The impact of trade restrictions on price stability in the world wheat market." *American Journal of Agricultural Economics* 59 (4):628-638.

Taplin, JH. 1969. "Demand in the World Wheat Market and the Export Policies of the United States." *Canada and Australia, Cornell University*.

Thompson, Stanley R, Wolfgang Gohout, and Roland Herrmann. 2002. "CAP reforms in the 1990s and their price and welfare implications: the case of wheat." *Journal of agricultural economics* 53 (1):1-13.

USDA. 2014. Agricultural Act of 2014. http://www.ers.usda.gov/agricultural-act-of-2014-highlights-and-implications.aspx.

Young, C Edwin, and Paul C Westcott. 2000. "How decoupled is US agricultural support for major crops?" *American Journal of Agricultural Economics* 82 (3):762-767.

Yu, Wusheng, and Hans G Jensen. 2010. "China's agricultural policy transition: impacts of recent reforms and future scenarios." *Journal of Agricultural Economics* 61 (2):343-368.

CHAPTER 2 THE INFLUENCES OF WHEAT GOVERNMENT STOCK POLICY IN CHINA: A COUNTERFACTUAL ANALYSIS

2.1 Introduction

Since 2006, the Chinese government used strategic reserves to influence domestic wheat market price and production. The grain reserve agency has the responsibility to procure wheat at the minimum support prices and sell this wheat in auctions. The minimum procurement prices are typically announced in October (at the beginning of the planting season), which might affect the farmers' plantation decision. The wheat procurement by the state reserve agency commences from the end of May and ends at the end of September. State reserve agency sells the wheat by weekly auction. Meanwhile, private traders are free to buy from farmers at any price. Despite the apparent increase in wheat price and production, few empirical studies have estimated how this policy of price and storage mechanisms affected the wheat market outcomes in the past eight years.

In the past century, progress has been achieved in studying grain price stabilization and competitive storage. First, Waugh (1944), Oi (1961), Massell (1969) and Newbery and Stiglitz (1979) developed and improved the theory of commodity price stabilization. Numerous studies were based on this theory, such as Turnovsky (1974) and Miranda and Helmberger (1988). Turnovsky (1974) analyzed the gains from price stabilization when supply decisions were based on price expectations and "adaptive" expectations and "rational" expectations, finding that the distribution of welfare among producers and consumers was related to the formation of price expectations, as well as the cause and properties of the random price fluctuations. Miranda and Helmberger (1988) assessed the effect of stabilization programs on the U.S. soybean market using a rational expectations

model, and indicated that price stabilization program had a negative effect on the long-run market price and producer revenue in stochastic simulations. Second, the theory of production and consumption with competitive storage was developed by Gustafson (1958), Muth (1961) and Samuelson (1971). Other important contributions include (Stiglitz (1981)), Newbery and Stiglitz (1982), Williams and Wright (1991), and Deaton and Laroque (1992). This approach assessed the relevance of speculative storage in explaining commodity price behavior. Applied studies of grain storage and public intervention based upon the competitive storage, such as Brennan (2003), also applied this method.

Grain price policies of many developing and developed countries have been analyzed. Examples include rice price and policies in Malaysia (Brown 1973), Bangladesh(Ahmed and Bernard 1989), India (Jha and Srinivasan 1999), and Argentina (Wogart 1983), as well as corn in the US (Holt 1994). Dawe (2001) argued that pure price stabilization for rice is important for rapid economic growth by increasing the quantity and efficiency of investment and to protect poor consumers and farmers from sharp price fluctuations, but he argued that the costs of intervention were too high. Cummings, Rashid, and Gulati (2006) analyzed grain price stabilization in Asia using case studies of six Asian countries, and concluded that private institutions should be strengthened significantly and entrusted to perform the functions that government agencies traditionally have undertaken.

Many studies addressed grain policies and procurement, such as Lin (1992), Lin and Tan (1999), Sicular (1995), Zhou, Wan, and Chen (2000), Rozelle et al. (2000), and Shea (2010). Yet, few researchers focused on the grain policy since China's accession to World Trade Organization (WTO). Even fewer have studied the influences of domestic

pricing policies and buffer stocks on wheat market in China between 2006 -2014. One exception, Yang, Wang, and Geng (2008), argued that the absence of a long-term equilibrium between China and world wheat market is necessary for the effectiveness of government intervention in wheat market. However, perhaps owing to how recent these policies were, China's wheat policy of 2006-2014 has not been subject to academic scrutiny in order to assess the market impacts. This article examines the effect of government stock policies on wheat market outcomes, including prices, production, consumption, and total stocks.

In examining the effect of grain stock policy, two methods were often used: rational expectation techniques (Srinivasan and Jha 2001, Brennan 2003) and partial equilibrium approaches (Zwart and Meilke 1979, Thompson, Gohout, and Herrmann 2002). Srinivasan and Jha (2001) used a multi-market equilibrium model assuming that the private storage agents were risk neutral and had tradition price expectations to analyze the effects of liberalizing food grain policies on domestic price stability. Brennan (2003) examined the price dynamics of the Bangladesh price market using dynamic programming techniques. Zwart and Meilke (1979) developed a theoretical model of price intervention and showed that modification of domestic pricing policies would have the similar effect as buffer stock policy in stabilizing the wheat market by stochastic simulation experiments. Thompson, Gohout, and Herrmann (2002) studied the impact of the CAP reforms on price and economic welfare in the European Union with an aggregate structural econometric model of the EU wheat economy. These examples suggested that both rational expectations and partial equilibrium approaches have been used for research questions relating to stocks and stock policies. Based on a partial

equilibrium method, I develop a simulation model of China wheat market, which is used to evaluate the effects of the stocks policy under different assumptions.

This article makes several contributions to the literature. The first is that it provides new empirical evidence on the effect of government stocks policy on grain market outcomes. Given the high level of government resources devoted to the grain price support, it should be useful to decision makers to have a better understanding of the effects of government stocks policy. I view this contribution as the primary objective of the exercise because I am not aware of any scientific assessment of how China's wheat stocks affected domestic market quantities and prices in the 2006 to 2014 period. The second contribution is that this study provides a useful comparison to grain policies in other developing countries in Asia, like India.

The remainder of the paper is organized as follows. In Section 2, I discuss the wheat support price policy in China and its evolution, the relationship between China and world wheat prices, as well as wheat trade policies and quantity in China. I present the analytical framework and simulation model of wheat market in China in Section 3. The simulate results without government stock policy are shown in Section 4. Sensitivity analysis is discussed in Section 5. Finally, in Section 6, I draw certain conclusions.

2.2 China and World Wheat Market

2.2.1 China wheat market and policy

Wheat is the dominant staple crop in the northern part of China, especially in the Henan, Shandong, Jiangsu, Anhui, Hubei, and Hebei Provinces. Wheat production in these six provinces accounts for more than 90% wheat production in China, which is presumably

the reason that wheat price support was implemented in only these provinces. Prior to wheat market policy reforms in 1990s, wheat marketing was manipulated by a vast network of bureaucratic agents through procurement, storage, transport, processing and selling grain, which indicated the influence of government over the economy was dominant, rather than market (Rozelle et al. 2000). In 2000, China established the state grain reserve agency *Sinograin*, a state enterprise, which used market-based mechanism to intervene in grain market. China started wheat support price policy for the first time in 2006. *Sinograin* delegated its own warehouses and other local grain warehouses to implement wheat procurement. Warehouses can get 5 yuan by purchasing 100kg wheat from the producers and get 7 yuan per 100 kg for one year storage.

Sinograin's wheat purchase and auction varied considerably over time as indicated in Table 1. First, I summarize the floor prices of different wheat varieties purchased by the state reserve agency *Sinograin* each wheat marketing year from 2006/07 to 2014/15, as well as the tonnage of wheat purchases and auctions on the domestic market. In 2006/07, the average wheat support price was 1380 yuan/ ton. The wheat support price did not increase very much in 2007/08 and 2008/09. However, the growth rate of wheat support price was 15% in 2009/10, while the growth rate was around 10% in both 2012/13 and 2013/14. Before the year 2012/13, wheat support prices were different for white wheat and red wheat. Second, the volume of wheat purchases fluctuated over time as shown in Table 1. From 2006/07 to 2009/10, wheat purchase quantities were as high as around 40 million tons, except the year 2007/08. The wheat procurement quantity dropped to 22.6 million tons in 2010/11. In 2011/12, because wheat market price was higher than support price consecutively in the first three days, the government did not purchase any wheat

from market. The wheat purchase quantity was only 8.4 million tons in 2013/14. Third, procured wheat was sold by auction weekly. In 2006/07, the state reserve agency sold 14.3 million tons of wheat from September to December. From the year 2007/08 to 2010/11, annual quantity of wheat sold by auctions was around 30 million tons. In 2011/12, only 5.55 million tons of wheat was sold in 2011/12 when there was no wheat purchase. In 2013/14, wheat auction volumes were 25.5 million tons, which was far greater than wheat procurement.

Government ending stocks changed a lot from 2006/07 to 2014/15. Government ending stocks first increased from 26.6 million tons in the year 2006/07 to 45.2 million tons in 2009/10, and then decreased each year. The total government stocks in 2013/14 were only 11.35 million tons. Therefore, the state grain reserve agency intervened in the market more in the early years of the program, but did not have very much wheat stocks at the end of the eighth year.

Table 2 summarizes the market prices of wheat and corn during 1998/99 to 2013/14. From 1998/99 to 2002/03, wheat price decreased year by year. In 2003/04, wheat production decreased to only 86.5 million tons, from 123.3 million tons, down by 30%. Since 2004, China cancelled the agricultural tax that was in place throughout the country. In order to assure the growth of wheat production, the government announced the minimum price support policy in 2006. From Table 2, some interesting insights can be observed. First, market prices in June in most years were lower than the average price during June to September and during June to May. Second, corn price was lower than wheat price for most years. When corn prices in some years were higher than wheat prices, wheat would likely be used as animal feed, especially during the period between

wheat harvest in June and corn harvest in September. Third, the average wheat market prices in June, June to September, and June to May, were always higher than the wheat support price from the year 2006/07 to the year 2013/14.

Table 13 Minimum support prices, purchase and auction quantity, 2006/07-2014/15 marketing year (yuan/ton; million tons)

	Support Price (Yuan/ton)			Quantity (million tons)			
	White	Red	Mixed	Procure	Auction	Production	State stocks
2006/07	1440	1380	1380	40.9	14.3	104	26.6
2007/08	1440	1380	1380	28.9	33.3	109	22.2
2008/09	1540	1440	1440	42	28	112	36.2
2009/10	1740	1660	1660	40	31	117	45.2
2010/11	1800	1720	1720	22.6	27.2	115	40.6
2011/12	1900	1860	1860	0	5.55	117	35.1
2012/13	2040	2040	2040	23.4	30	121	28.5
2013/14	2240	2240	2240	8.4	25.5	122	11.5
2014/15	2360	2360	2360	n.a.	n.a.	n.a.	n.a

Notes: White, Red, Mixed represents different varieties of wheat.

Sources: The official documents released by the Chinese government from 2005 to 2014.

Table 14 Corn and wheat price averages in the marketing years (yuan/ton)

	June to May		June to September		June		Wheat Support Price
	corn	wheat	corn	Wheat	corn	wheat	
1998/99	1274	1440	1342	1410	1312	1352	
1999/00	1006	1200	1102	1325	1150	1408	
2000/01	1030	1092	947	1088	922	1116	
2001/02	1090	1090	1208	1096	1201	1062	
2002/03	1037	1066	1042	1043	1044	1038	
2003/04	1200	1315	1084	1084	1068	1073	
2004/05	1263	1570	1347	1552	1327	1514	
2005/06	1218	1450	1232	1468	1202	1476	
2006/07	1405	1494	1358	1418	1337	1419	1380
2007/08	1604	1573	1564	1520	1547	1510	1380
2008/09	1543	1725	1643	1629	1642	1594	1440
2009/10	1761	1915	1700	1844	1579	1811	1660
2010/11	1988	2030	1945	1975	1936	1947	1720
2011/12	2256	2096	2260	2047	2168	2058	1860
2012/13	2291	2278	2349	2131	2318	2099	2040
2013/14	2250	2485	2291	2418	2259	2341	2240

Sources: date center of cngrain.com.

Table 3 summarizes the farmers' prices in different provinces. First, the regional differences in wheat prices are apparent. The prices in Hebei and Shandong were higher than prices in other provinces, national average prices and minimum support prices. Hubei wheat price was the lowest among these six provinces while its wheat production was also the lowest among these provinces. Second, the national average farmers' prices during this period were higher than minimum support price. In 2012 and 2013, wheat farmers' prices in Hebei, Shandong and Anhui were higher than minimum support price while wheat prices in Jiangsu, Henan and Hubei were lower than minimum support price. Overall, however, farm prices of wheat were generally higher than support prices in most provinces during the past years.

Table 15 Differences between provincial farm prices and national support price (yuan/ton)

	National	**Hebei**	**Jiangsu**	**Anhui**	**Shandong**	**Henan**	**Hubei**
2006	1432	1487	1386	1408	1453	1443	1334
2007	1512	1578	1439	1425	1606	1496	1355
2008	1655	1669	1545	1527	1678	1633	1519
2009	1848	1981	1741	1731	1911	1866	1541
2010	1980	2066	1914	1874	2046	1935	1810
2011	2079	2102	1964	1957	2122	2021	1960
2012	2166	2276	2030	2089	2341	1985	1897
2013	2356	2494	2230	2259	2472	2209	2101
The difference between farm price and support price							
2006	52	107	6	28	73	63	-46
2007	132	198	59	45	226	116	-25
2008	215	229	105	87	238	193	79
2009	188	321	81	71	251	206	-119
2010	260	346	194	154	326	215	90
2011	219	242	104	97	262	161	100
2012	126	236	-10	49	301	-55	-143
2013	116	254	-10	19	232	-31	-139

Sources: National Agricultural Products Costs and Revenue Yearbook, 2007-2014

2.2.2 World and China wheat price

Figure 1 represents monthly domestic and foreign wheat prices from 1998 to 2014. Before the year 2006, the difference of wheat price between China and world market was relatively small. Meanwhile, China was a net importing country of wheat. After the Chinese government began to implement the minimum procurement policy in 2006, wheat price in China increased year after year. World wheat price remained volatile, reaching 439 dollars per ton during the 2007-2008 food crisis while the wheat price in China was less than 250 dollars per ton at that time period. After this food crisis, world wheat price dropped while China wheat price continued rising. Moreover, China wheat prices were higher than world wheat price for most of the time after the year 2008.

Table 4 shows the mean and coefficient of variation of domestic and international wheat price from 1998 to 2013. During this period, the mean price of wheat in China was higher than the mean value of international wheat price for the most years. Moreover, the coefficient of variation of China wheat price was lower than that of world market price, except in the year 1999 and 2003. In the year 2002, 2007, 2008, 2012, the world wheat price fluctuations were greater than average. For China, the wheat price variation after 2006 was smaller as compared to variation in previous years.

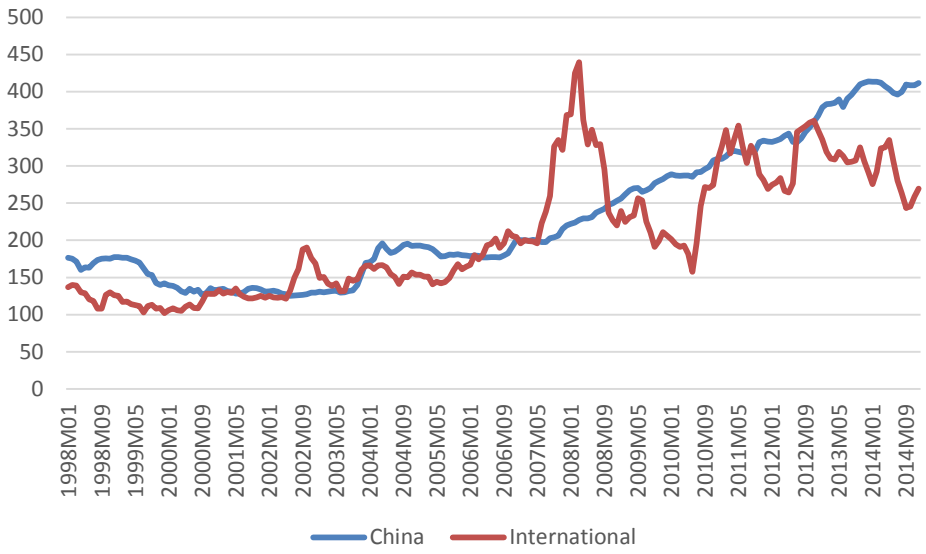

Figure 9 Historical China and world wheat market price

Sources: China monthly price from Zhong Hua Liang Wang, which was transformed by the exchange rate from IMF; International wheat monthly price from IMF.

Table 16 Mean price and coefficient of variation of China and world price

	Domestic Price		International Price		Difference	
	Mean	CV	Mean	CV	Mean	CV
1998	171	3.5	126	8.5	45	-5.0
1999	162	9.1	112	5.6	50	3.5
2000	133	3.0	114	8.0	19	-5.0
2001	132	2.0	127	3.5	5	-1.5
2002	128	1.8	149	18.3	-21	-16.5
2003	137	9.1	146	7.0	-9	2.1
2004	187	4.3	157	5.1	30	-0.8
2005	184	2.9	152	6.0	32	-3.1
2006	181	4.0	192	7.2	-11	-3.2
2007	204	3.5	255	25.5	-51	-22.0
2008	236	4.4	326	21.9	-90	-17.5
2009	271	3.2	223	9.2	48	-6.0
2010	293	2.8	224	21.2	69	-18.4
2011	321	2.4	316	8.3	5	-5.9
2012	343	3.4	313	13.3	30	-9.9
2013	394	3.3	312	3.6	82	-0.3

Sources: collected and calculated by the author.

Next, the relationship between China wheat price and world wheat price is explored using unit root and cointegration tests. First, I test the stationarity of the two time series. Both China wheat price and world wheat prices were not stationary, but their first differences

were stationary. Second, I test the correlation of the first difference of China wheat price and world wheat price during the period 1998-2014. The correlation of their first differences from 1998 to 2014 is only 0.04, which means that wheat price change in China did not follow the trend of world price change. Third, the conclusion that the analyzed series were integrated of first order allowed us to conduct a cointegration test. The results indicate that there was no long-run stable relationship between China wheat price and world wheat price. The results also suggest that there was some serious policy buffering going on that separates China from the rest of the world even in the long run. For example, the license system could limit China's exports and imports in a way that causes this result. Finally, I also perform Granger Causality test. Test results show that China wheat price does not Granger-cause world wheat price, or vice versa. Therefore, these tests lead to the conclusion that it is not appropriate to link China wheat price with world market price in a China wheat market model.

Table 17 Unit root test with ADF

	Lags	Level	First Difference
China wheat price	4	0.092	-5.338***
World wheat price	2	-1.364	-9.413***

Source: estimated by the author.

Table 18 Co-integration test between China wheat price and world wheat price

	Test Statistic	1% *	5% *	10% *
W/ constant	-1.915	-3.476	-2.883	-2.573
W/constant & trend	-2.261	-4.006	-3.437	-3.137

Note: * represents critical values.
Source: estimated by the author.

2.2.3 China wheat trade policy and quantity

After China's accession to WTO, the China wheat import tariff quota was set at 9.636 million tons, which is less than 10% of wheat production in China. Of the quota, 90% was allocated to state-owned enterprises solely operated by China National Cereals, Oils

and Foodstuffs Corporation (COFCO). Only 10% was allocated to private enterprises. Wheat export in China was managed by a license system. COFCO is responsible for the issue of export license. However, as a state-owned enterprise, COFCO needs to comply with the command of the government.

China imported 4 million tons to as much as 16 million tons of wheat before the year 1995/1996. After the Household Responsibility System (HRS) was implemented gradually in 1978-1984, China then did not import as much wheat from the world market.

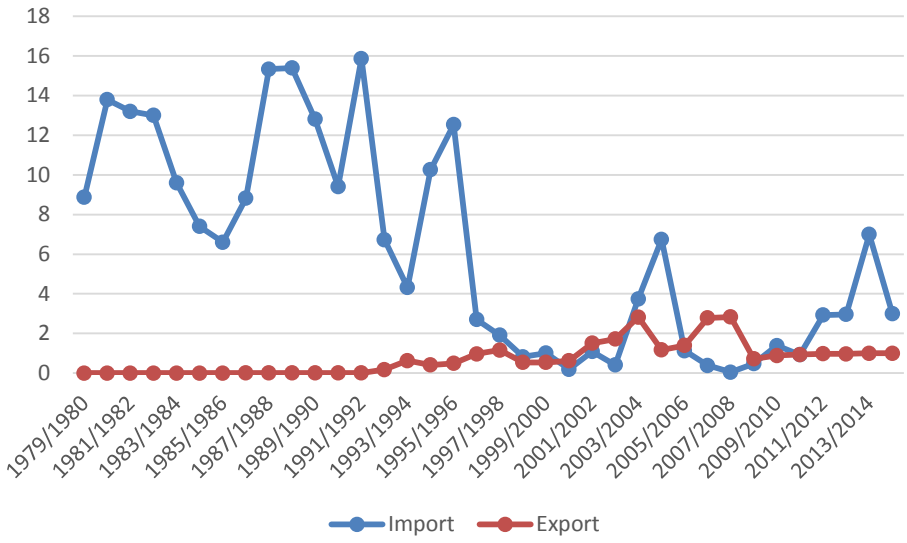

Figure 10 Historical quantities of China wheat import and export
Source: trade data from USDA.

I test the stationarity of the time series of wheat imports, wheat exports, China wheat price, and world wheat price with augmented Dickey-Fuller (ADF) tests (Table 7 and Table 8). The results indicate that imports, exports, china wheat price, and world wheat prices were not stationary, but their first differences were stationary. Moreover, I perform cointegration tests between imports, exports and prices using the Engle-Granger test. The

short run correlations between what imports, wheat exports and prices are estimated using their first differences, which are low as indicated in Table 20. The results in Table 20 also show that there was no cointegration relationship between exports and prices. When I use the ADF test with constant and without trend, imports and China wheat price had long run relationship, but there was no cointegration relationship according to the ADF test with constant and trend. These test results are taken to indicate that it is appropriate to treat wheat trade as exogenous in a model of China's wheat markets. Here I would like to admit the risk of assuming trade as exogenous. The government could also achieve the goal of price stabilization by combining import and export policies. When the market price is lower than support price, the government might provide export subsidies to encourage export. When the market price is higher than support price, the government might reduce import tariff to increase import and decrease domestic market price. In this case, the end of government stocks would have no effect on China's wheat price, production, or use. Instead, there would just be some offsetting changes in trade.

Table 19 Unit root test with ADF

	Lags	Level	First Difference
Import	1	-2.229	-5.68***
Export	1	-2.105	-6.26***
Ln(China wheat price)	2	-1.35	-3.456***
Ln(World wheat price)	1	-2.475	5.744***

Notes: Lags was chosen by AIC. *** indicates significant at 1% level. The 1%, 5%, 10% critical values for ADF and PP tests are -3.709, -2.983, -2.623 respectively.

Table 20 Short run correlations and co-integration test

	Short run correlations	Lags	ADF w/ cons	ADF w/cons and trend
Import and Price	0.25	1	-2.673*	-2.657
Export and price	-0.19	1	-2.448	-2.286
Import and world price	0.26	1	-2.553	-2.827
Export and world price	0.28	1	-2.045	-2.140

Notes: Lags was chosen by AIC. ***, **, and * indicate significant at the 1% level, the 5% level, and the 10% level, respectively. The 1%, 5%, 10% critical values for ADF tests with constant are -3.709, -2.983, -2.623 respectively. The 1%, 5%, 10% critical values for ADF tests with constant and trend are -4.275, -3.576, -3.226 respectively.

2.3 Method and Data

My theoretical framework consists of two components. First, I develop a partial equilibrium model of China's wheat market. Second, I perform counter-factual experiments under different scenarios based on the wheat model to test the effect of government stocks on wheat market outcomes. Moreover, I do the sensitivity analysis by comparing the simulation results for alternative speeds of supply response, alternative degrees of displacements between government stocks and private stocks, alternative corn prices, and alternative price elasticities of stock demand.

2.3.1 Wheat market model

China's wheat market model includes production, food use, feed use, private and government stocks, imports and exports. Wheat planting area depends on real returns per hectare of the previous year. Wheat yield increases over time due to technical progress, which may include improvements in seed, fertilizer, and agriculture machinery. Per capita wheat consumption as food is related to previous per capita wheat food use, wheat price, and per capita income. Wheat feed use is associated with the price difference between corn price and wheat price, wheat beginning stocks, and income level. Some wheat is stored for a long time, even more than 5 years, and this kind of wheat is usually sold as feed use when it is eventually used. And wheat stocks are more likely to be used for feed if the wheat price is lower than corn price. Private stock for wheat is expected to depend on price, government wheat stocks, and total supply, including production and beginning stocks. In addition, I assume that wheat imports and exports are exogenous. For the Chinese wheat market, the market clears when total supply, including production, beginning stocks, import, is equal to total demand, which equals the sum of wheat food

use, wheat feed use, private stocks, government stocks and export. The market-clearing equation solves for the market price of wheat in China. The model has 5 equations and 3 identities, which are defined as follows. Equations (1) – (5) represent production area, yield, per capita wheat food use, feed use, and private stocks, respectively. The parameters of these equations are estimated, as discussed below. Equations (6)-(8) are identities for wheat production, wheat food use, and the wheat market clearing condition. The equations are listed as follows.

$$AA_t = \alpha_o + \alpha_1 P_{t-1} * YY_t + \alpha_2 AA_{t-1} + \mu_t \quad (1)$$

$$YY_t = t_0 + t_1 T + \omega_t \quad (2)$$

$$PFU_t = \beta_0 + \beta_1 PFU_{t-1} + \beta_2 P_t + \beta_3 PINC_t + \vartheta_t \quad (3)$$

$$FEU_t = \gamma_0 + \gamma_1 \max(0, CP_t - P_t) + \gamma_2 BS_t + \gamma_3 INC_t + \varepsilon_t \quad (4)$$

$$PS_t = \delta_0 + \delta_1 P_t + \delta_2 (QS_t + PS_{t-1}) + \delta_3 GS_t + \tau_t \quad (5)$$

$$QS_t = AA_t * YY_t \quad (6)$$

$$FU_t = PFU_t * POP_t \quad (7)$$

$$QS_t + PS_{t-1} + GS_{t-1} + QI_t = FU_t + FEU_t + PS_t + GS_t + QE_t \quad (8)$$

The endogenous variables AA, *YY*, *P*, *PFU*, *FEU*, *PS*, *QS*, and *FU* represent wheat production area, wheat yield, wheat market price, per capita food use, feed use, private stocks, wheat production, food use, respectively. The exogenous variables *T*, *PINC, INC, BS*, *GS*, *POP*, *QI*, and *QE* are time trend, per capita income, income, beginning stocks, government stocks, population, wheat imports, and wheat exports, respectively. Subscript *t* indicates year. $\mu, \omega, \vartheta, \varepsilon, \tau$ are residuals.

2.3.2 Data

Production data are from China Agricultural Yearbook, and demand data from USDA. Price data are from World Bank and China agricultural products costs and revenues yearbook. Consumer price index (CPI) data are from Chinese Statistical Yearbook. Monthly market prices of wheat and corn are from Zhong Hua Liang Wang (datacenter.cngrain.com). Data representing monthly international wheat price and the exchange rate between RMB and US dollars are from International Monetary Fund (IMF).

2.3.3 Wheat model parameterization

I estimate equation (1)-(4) based on the historical data from 1998/99 to 2013/14. Since wheat support prices were lower than the wheat market prices in previous years during the period 2006-2014 and consequently the announced support price presumably seems unlikely to be a better measure the price producers expected, I use wheat market price instead of procurement price in the equations of the model. The regression results are presented in Table 9 based on three estimation methods. Because the supply and demand balance determines market price and price can also affect supply and demand, simultaneity problems are common in the market estimation. Two-stage Least Square (2SLS) and full information maximum likelihood (FIML) are used to deal with simultaneity bias. In the estimation with 2SLS, unit area return, lagged area, trend, real GDP, real GDP per capita, real corn price, and beginning stocks are used as instrument variables. Since FIML is efficient, the parameters obtained by FIML are used in the wheat structure model for simulation. The coefficient of lagged dependent variable is 0.86, which might cause some problems, so I do a sensitivity test by imposing several values to the parameter of lagged area. The tests hold the unit area return term constant,

so only long-run area response changed. The results indicate that the model is not sensitive to the parameter of lagged area over the year 2006/07-2013/14.

Table 21 Regression results of parameters in the model with different methods, 1998/99-2013/14

OLS regression	**Adjusted R^2**
Eq(1) $AA_t = 1.12 + 0.44P_{t-1} * YY_t + 0.82AA_{t-1}$ (3.63) (0.10)*** (0.22)*	0.84
Eq(2) $YY_t = 3.52 + 0.10T$ (0.08)*** (0.01)***	0.92
Eq(3) $PFU_t = 91.65 - 5.95P_t - 0.24PINC_t$ (7.29)*** (4.64) (0.08)***	0.68
Eq(4)$FEU_t = -21.08 + 38.32 \max(0, CP_t - P_t) + 0.20BS_t + 0.08\, INC_t$ (2.90)*** (18.56)* (0.03)*** (0.01)***	0.92
2SLS method	**Adjusted R^2**
Eq(1) $AA_t = 1.12 + 0.44P_{t-1} * YY_t + 0.82AA_{t-1}$ (3.63) (0.22)* (0.10)***	0.84
Eq(2) $YY_t = 3.50 + 0.10T$ (0.08)*** (0.01)***	0.92
Eq(3) $PFU_t = 94.16 - 9.32P_t - 0.21PINCt$ (9.31) (6.62) (0.09)**	0.67
Eq(4) $FEU_t = -22.09 + 13.70 \max(0, CP_t - P_t) + 0.21BS_t + 0.08\, INC_t$ (4.00)*** (60.28) (0.03)*** (0.01)***	0.91
FIML	**Adjusted R^2**
Eq(1) $AA_t = 0.38 + 0.86AA_{t-1} + 0.38P_{t-1} * YY_t$ (10.25) (0.21)*** (0.88)	0.85
Eq(2) $YY_t = 3.53 + 0.10T$ (0.16)*** (0.03)***	0.92
Eq(3) $PFU_t = 93.54 - 8.95P_t - 0.21PINCt$ (32.63)** (26.8) (0.43)	0.72
Eq(4) $FEU_t = -16.25 + 49.08 \max(0, CP_t - P_t) + 0.15BS_t + 0.07\, INC_t$ (28.33)*** (103.9) (0.31) (0.04)*	0.92

Sources: estimated by the author.

From the regression results in Table 10, market returns per hectare does not have statistically significant effect on wheat planting area, but is nevertheless important in terms of measured elasticity, and the previous year's area has an important effect possibly due to delays in adjusting farmers' planting practices. Wheat yield significantly increases with time trend, which may be brought about by long-term technical progress. Both wheat price and income per capita have negative effects on food use per capita, but not significantly. The parameter of income in the feed use equation is statistically significant.

Feed demand is highly related to meat consumption, which has increased with income growth in China. The beginning stocks variable is used in the feed use equation, rather than total supply, since wheat stocks from previous years are more likely to be used as feed for livestock and poultry. The maximum value between zero and corn price minus wheat price is used as one factor in wheat feed use, and its parameter is the most sensitive one among the estimation with different techniques. The might be caused by frequent zeros, the big range from 0 to several hundred, and the small amount of feed use. Because very limited data representing private stock holding are available, it is less likely to estimate equation (5) directly. Instead, this study uses the price elasticity of demand from Zhuang and Abbott (2007). It is assumed that the price elasticity of private stock demand is -0.83 based on their work. The crowding out effect of government stocks, δ, is defined as the units of private stocks change if government stocks increase one unit. The baseline value of this parameter is -0.8. The total wheat supply also has the effect on private stock demand. Based on the assumptions for price elasticity of stock demand and the parameter of government stocks crowding out effect with the data of private stocks and total wheat supply, this study uses private stock data from 2006/07 to 2013/14 and estimates the parameter of total supply to be 0.62.

In the estimated model, the elasticities are reasonable as compared to other studies. According to our results, the short run price elasticity of supply in 2006/07 to 2013/14 is 0.12 while the long run elasticity is 0.88. The price elasticity of wheat food demand is -0.20. The income elasticity of wheat food demand is -0.07. These elasticities are consistent with other authors' findings in the past. For example, our short run elasticity of wheat supply is higher than the 0.049 estimate of Rozelle and Huang (2000), but not by a

large difference. Our income elasticity of demand is quite close to the estimates used in USDA grain models and Huang et al (1997). Zhuang and Abbott (2007) estimated the price elasticities of wheat stock demand, which informed the values used in this study, which were -0.827 and -1.110. However, these authors used a different form of simultaneous equation model of Chinese agricultural markets for wheat, rice, corn, pork, and poultry meat and AIDS model for food demand.

Table 22 Elasticities used in our model and other studies

	Elasticity			
	Supply	**Demand**	**Income**	**Period**
This study	0.12	-0.2	-0.07	1998-2013
Rozelle, Huang	0.049			1975-95
Zwart, Meilke		-0.1		1979
Riethmuller, Roe		-0.18 (Japan)	0.006 (Japan)	1960-81
Srinivasan, Jha	0.09 (India)	-0.58(India)		
Zhang and Abbott	0.348			1978-2001
Huang et al	0.53*		0.00r	2000-10
	0.04*		-0.05r	2010-20
			-0.05u	2000-10
			-0.1u	2010-20
USDA	-0.36*			1990-2000
	0.02 *		-0.06 to -0.01 u	2000-10
			0.10 to 0.12 r	2000-10

Notes: * represent area planted elasticity; u represents urban; r represents rural.

I establish China wheat partial equilibrium model with the parameters estimated by FIML and assumed based on Zhuang and Abbott (2007). The model fit is measured over the historical data in the period 2006/07-2013/14. During the period, 98% of the variation in both wheat area and yield are explained. The model can account for 98% of the variation in food consumption per capita. In addition, 82% of variation in wheat feed use is explained while 79% of changes in total ending stocks is accounted for.

2.4 Simulated Results

The model does not include the procurement prices since it was almost never binding over the year 2006/07~2013/14, and it assumes that there were no procurement prices in alternative policies. In the baseline, the price elasticity of stock demand was -0.83, and the crowding out effect of government stocks on private stocks was -0.8. As a first step, however, the baseline model is calibrated to actual historical data. Thus, policy impacts can be expressed as changes from actual data. I simulate wheat market prices and other endogenous variables assuming no government stocks with the China wheat model, in order to show the impacts of government stock policy on wheat market outcomes.

Table 11 reflects the comparison of the simulation results without government stocks and historical values. First, the results indicate that wheat market price would be lower without the government stock policy during the years from 2006/07 to 2010/11. The average wheat market price in this period would be around 7% lower without government stocks policy. However, the wheat price in 2013/14 would be higher without the government stocks policy, at 2711 yuan/ton or 226 yuan per ton (9.1%) higher than the historical value. Second, from 2006/07 to 2013/14, the wheat price would rise from one year to the next even without government policy. This result suggests that the government stock policy by itself does not explain all of the underlying factors driving this price higher in this period. Moreover, the standard deviation of wheat price during the years 2006/07 to 2013/14 would be 449 yuan/ton without government stock policy as compared to 343 yuan/ton with government stock policy. This means that government stocks policy stabilized wheat market prices, at least by this measure. Third, total ending stocks would be much lower without government stock policy. In the absence of

government stocks, the private ending stocks would be higher from 2006/07 to 2012/13, but would be lower in 2013/14. Fourth, wheat production and planted area would decrease 1-3%. These results suggest that this government stock policy might have increased wheat production and stabilized wheat market prices in these eight years, yet also leads to lower and more volatile stock levels as well as, presumably, public costs that are not identified in this analysis.

Table 23 Effects of government stocks policies on wheat market outcomes

	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14
Historical values								
Price	1494	1573	1725	1915	2030	2096	2278	2485
Planted area	23.6	23.7	23.6	24.3	24.3	24.3	24.3	24.1
Production	108	109	112	115	115	117	121	122
Food use	98	98	97.5	97	97.5	98.5	100	100.5
Feed use	4	8	8	10	13	24	25	23
Private stocks	12	17	10	9	18	21	26	47
Government stocks	27	22	36	45	41	35	28	11
Scenario results								
Price	1386	1536	1591	1759	1971	2100	2350	2711
Planted area	23.6	23.5	23.4	23.9	23.6	23.6	23.7	23.8
Production	108	108	111	113	112	114	118	120
Food use	99	98	99	99	98	98	99	99
Feed use	5	10	8	10	14	24	25	23
Private stocks	36	34	38	43	43	37	34	38
Government stocks	0	0	0	0	0	0	0	0
Difference, absolute								
Price	-108	-36	-134	-156	-60	4	72	226
Planted area	0	-0.2	-0.2	-0.4	-0.6	-0.6	-0.5	-0.4
Production	0	-0.9	-1.1	-2	-2.9	-3	-2.7	-1.8
Food use	1.4	0.4	1.5	1.6	0.6	0	-0.6	-2
Feed use	1	1.8	0	0.1	0.7	-0.1	-0.5	0
Private stocks	24	17	28	33	24	16	8	-9
Difference, relative (%)								
Price	-7.2	-2.3	-7.8	-8.1	-2.9	0.2	3.2	9.1
Planted area	0	-0.8	-1	-1.8	-2.6	-2.6	-2.2	-1.5
Production	0	-0.8	-1	-1.8	-2.6	-2.6	-2.2	-1.5
Food use	1.4	0.4	1.5	1.7	0.6	0	-0.6	-2
Feed use	25.1	22.7	0	0.9	5.2	-0.6	-2	0
Private stocks	202	99	292	361	132	77	31	-19

Sources: estimated by authors.

Notes: Price unit is yuan/ton, area unit is million ha, wheat yield unit is ton/ha, and the unit of production, food use, feed use, and ending stocks are million tons.

2.5 Sensitivity Analysis

In this section, the robustness of the results is assessed using sensitivity analysis that focuses on different factors in the private stocks equation, including the crowding out effect of government stocks and private price elasticity, and corn price.

First, I test the sensitivity of government stocks assuming different degrees of displacement between the government stocks and private stocks. The simulated results

are shown in Table 12. If the crowding out effect of government stocks is -0.7, compared to the baseline scenario with the displacement degree -0.8, the average price between 2006/07 and 2013/14 would decrease to 1925 yuan/ton from 1926 yuan/ton of the baseline scenario without government stocks. Average private ending stocks without government stocks would drop from 38 million tons in the base case to 31 million tons. If the crowding out effect of government stocks is -0.9, as compared to the baseline value of -0.8, then the average wheat market price in the absence of government stocks would be 1934 yuan/ton rather than 1926 yuan/ton of the baseline case. Average private ending stocks without government stocks would be 44 million tons instead of 38 million tons. From the relative differences among scenarios, the simulated results are not very sensitive to the degrees of displacement, especially when the absolute value of displacement degree becomes smaller.

Table 24 Sensitivity analysis of degrees of displacement between government stocks and private stocks, 2006/07-2013/14 averages, change from historical values

	Base degree of displacement	Alternative degrees of displacement	
	0.8	0.7	0.9
Scenario Results			
Price	1926	1925	1934
Planted area	24	24	24
Production	113	113	114
Food use	99	99	99
Feed use	15	15	14
Private stocks	38	31	44
Difference between scenario and base, absolute			
Price	-24	-25	-16
Planted area	-0.4	-0.5	-0.2
Production	-1.8	-2.4	-1.0
Food use	0.3	0.4	0.2
Feed use	0.4	0.9	0.0
Private stocks	18	11	24
Difference between scenario and base, relative (%)			
Price	-2.0	-2.3	-1.2
Planted area	-1.6	-2.0	-0.9
Production	-1.6	-2.0	-0.9
Food use	0.4	0.4	0.2
Feed use	6.4	15.3	1.2
Private stocks	147	109	183

Sources: estimated by authors.

Notes: * represents the average value of the absolute differences between scenario value and historical values during the period 2006/07-2013/14; ** represents the average value of the relative differences between scenario value and historical values during the period 2006/07-2013/14.

Second, I simulate the model under different scenarios of corn price changes, as shown in Table 13. The corn price appears only in the feed use equation. If corn price is reduced by 5% relative to actual historical values over the period 2006/07 to 2013/14, the wheat average price would change from 1926 yuan/ton in the baseline case without government stocks to 1920 yuan/ton. If the corn price decreases by 10%, then the scenario without government stocks results in 1919 yuan/ton wheat price as compared to the 1926 yuan/ton of the base case. Compared to baseline, the corn price change would only have minor effect on average wheat prices, feed use, and average ending stocks, and would

hardly affect wheat production, food use, and planted area. The non-linearity of response in feed use might remain very important for larger relative price changes, particularly if the corn price decreases dramatically, but a roughly similar change in corn and wheat prices as explored here might not bring about large enough changes in wheat feed use to drive wheat market results.

Table 25 Sensitivity analysis of corn price changes, 2006/07-2013/14 averages, change from historical values

	Base corn price	Alternative percentage of corn price change	
		5%	10%
Scenario Results			
Price	1926	1920	1919
Planted area	24	24	24
Production	113	113	113
Food use	99	99	99
Feed use	15	14	14
Private stocks	38	38	38
Difference between scenario and base, absolute			
Price	-24	-29	-30
Planted area	-0.4	-0.4	-0.5
Production	-1.8	-2.1	-2.2
Food use	0.3	0.4	0.4
Feed use	0.4	0.1	0.0
Private stocks	18	18	18
Difference between scenario and base, relative (%)			
Price	-2.0	-2.4	-2.5
Planted area	-1.6	-1.8	-1.9
Production	-1.6	-1.8	-1.9
Food use	0.4	0.4	0.5
Feed use	6.4	1.2	0.0
Private stocks	147	149	149

Sources: estimated by the author.

Notes: *represents the average value of the absolute differences between scenario value and historical values during the period 2006/07-2013/14; ** represents the average value of the relative differences between scenario value and historical values during the period 2006/07-2013/14.

Third, I simulate the model results under different scenarios about the price elasticity of private wheat stock demand. I use -0.83 from Zhang and Abbott (2007) as the price elasticity of stock demand at the baseline, and simulate under two alternative price

elasticities of stock demand, namely -0.44 and -1.22. The alternative price elasticities of private stock demand had minor effects on overall wheat price and ending stocks (Table 14). Moreover, the price changes more if the private stocks are less responsive to price. The change in price elasticity of private stock demand mostly affects the market price and private stocks, but has the negligible effect on other variables.

Table 26 Sensitivity analysis of price elasticity of stock demand, 2006/07-2013/14 averages, change from historical values

	Base price elasticity of stock demand	**Alternative price elasticities**	
	-0.83	-0.44	-1.22
Scenario Results			
Price	1926	1945	1932
Planted area	24	24	24
Production	113	113	113
Food use	99	99	99
Feed use	15	15	15
Private stocks	38	36	39
Difference between scenario and base, absolute			
Price	-24	-4	-17
Planted area	-0.4	-0.4	-0.4
Production	-1.8	-2.0	-1.8
Food use	0.3	0.2	0.3
Feed use	0.4	0.4	0.3
Private stocks	18	16	19
Difference between scenario and base, relative (%)			
Price	-2.0	-1.3	-1.7
Planted area	-1.6	-1.7	-1.5
Production	-1.6	-1.7	-1.5
Food use	0.4	0.2	0.3
Feed use	6.4	9.0	5.0
Private stocks	147	135	158

Sources: estimated by the author.

Notes: * represents the average value of the absolute differences between scenario value and historical values during the period 2006/07-2013/14; ** represents the average value of the relative differences between scenario value and historical values during the period 2006/07-2013/14.

The standard deviations of wheat market outcomes shown in Table 15 are summarized for the different scenarios. First, by comparing the variation of wheat prices from 2006/07 to 2013/14 with different scenarios, the standard deviation of historical prices is

the lowest, at 343 yuan/ton, while the standard deviation of price without government stocks ranges from 396 yuan/ton to 498 yuan/ton. Second, if I compare the variations of planted area and production, the standard deviations of historical values are greater than the values of any scenarios without government stocks. Although the standard deviation of the wheat market price in the historical data with government stocks is lower, wheat area and production varied more in these years with the government policy than they would have without it. The greater variation in supply-side variables in the presence of government stocks might be explained by the assumption that the procurement prices are irrelevant to farmer decisions in the historical period I examine. Third, the standard deviations of food use and feed use in the historical data are also higher than any scenarios, especially food use. Finally, the differences in standard deviation of private ending stocks between historical values and any other scenarios are very big, which indicate that increased volatility in ending stocks bring about the stabilization of wheat market prices in this period.

Table 27 Standard deviation of key wheat market variables under different scenarios

	History	Baseline scenario*	Displacement degrees		Corn price change		Price elasticities	
			0.7	0.9	0.05	0.1	-0.44	-1.22
Price	343	449	495	396	465	471	498	458
Planted area	0.31	0.15	0.13	0.21	0.15	0.16	0.16	0.15
Production	4.95	4.24	4.09	4.54	4.19	4.19	4.36	4.25
Food use	1.25	0.46	0.71	0.71	0.47	0.50	0.71	0.43
Feed use	8.37	7.87	7.35	8.17	8.24	8.37	7.56	8.00
Private stocks	12.32	3.56	4.14	5.28	3.63	3.68	3.11	4.69

Sources: estimated by the author.

Notes: * represents the scenario using the parameters of the baseline and without government stocks.

2.6 Conclusions

After China's accession into WTO, the government used strategic reserve and marketing auctions to influence grain market outcomes. Yet, to date, relatively little is known about how these strategic stock policies affect grain market prices in China. In this article, I establish a framework based on a standard partial equilibrium method, analyze the effect of government stocks policy on the China wheat market, and perform the sensitivity analysis under alternative assumptions.

I estimate the parameters in the wheat partial equilibrium model and simulate the market outcomes without government stocks. By counterfactual analysis, I demonstrate the effect of government buffer stocks on wheat market outcomes. According to these estimates, the government stocks policy reduces wheat market price volatility, and raises wheat production in China. However, there are some limitations. First, this study does not consider the total welfare effects of this policy. The policy is estimated to raise the wheat prices in the first five years of the period, but reduce the prices in the last three years. Knudsen and Nash (1990) argued that an effect of price stabilization policies is to transfer income from one group to another. From this perspective, income was transferred from consumers to producers in the first five years, and then reversed in the later years. Second, the potential for deadweight loss and taxpayer costs, as well as trade policies are also ignored in this study. Third, the model results might not hold if China just offsets the no-stock scenario impacts by changing its exports and imports.

In order to show the reliability of these findings, I also conduct several types of sensitivity analysis. The examination focuses on key uncertainties: the price elasticities of stock demand, the corn price change, and the displacement effect between government

stocks and private stocks. The results of sensitivity analysis indicate that the wheat market model is relatively stable, and not sensitive to corn price changes, or the displacement degree between government stocks and private stocks. Therefore, the simulated results based on the model are robust at least with respect to changes in these factors. Even though the parameter results seem to be consistent with economic theory and with other studies and experiments, the very limited availability of data that are relevant to this market, as well as questions about the quality of these data, are sources of uncertainty.

The results of this study have implications for the evaluation of similar policies for other grains in China and even other developing countries, especially those in pursuit of food security and price stabilization. In this case, the government stock policy reduced price variation and increased production. However, the cost incurred by this policy might not be trivial. Timmer (1989) discussed the cost of price stabilization, including the expenditure of public resources, and the destabilization of some other part of the economy, like government budget or the credit system. These policies also have costs on consumers, in the form of higher food commodity prices, and that results might be sensitive to other factors I have not explored, like trade policies.

REFERENCES

Ahmed, Raisuddin, and Andrew Bernard. 1989. *Rice price fluctuation and an approach to price stabilization in Bangladesh*: International Food Policy Research Institute.

Brennan, Donna. 2003. "Price dynamics in the Bangladesh rice market: implications for public intervention." *Agricultural Economics* no. 29 (1):15-25.

Brown, CP. 1973. "Rice price stabilization and support in Malaysia." *The Developing Economies* no. 11 (2):164-183.

Cummings, Ralph, Shahidur Rashid, and Ashok Gulati. 2006. "Grain price stabilization experiences in Asia: What have we learned?" *Food Policy* no. 31 (4):302-312.

Dawe, David. 2001. "How far down the path to free trade? The importance of rice price stabilization in developing Asia." *Food Policy* no. 26 (2):163-175.

Deaton, Angus, and Guy Laroque. 1992. "On the behaviour of commodity prices." *The Review of Economic Studies* no. 59 (1):1-23.

Gustafson, Robert L. 1958. "Implications of recent research on optimal storage rules." *Journal of Farm Economics*:290-300.

Holt, Matthew T. 1994. "Price-band stabilization programs and risk: an application to the US corn market." *Journal of Agricultural and Resource Economics*:239-254.

Jha, Shikha, and PV Srinivasan. 1999. "Grain price stabilization in India: Evaluation of policy alternatives." *Agricultural Economics* no. 21 (1):93-108.

Knudsen, Odin, and John Nash. 1990. "Domestic price stabilization schemes in developing countries." *Economic development and cultural change*:539-558.

Lin, Justin Yifu. 1992. "Rural reforms and agricultural growth in China." *The American economic review*:34-51.

Lin, Justin Yifu, and Guofu Tan. 1999. "Policy burdens, accountability, and the soft budget constraint." *American Economic Review*:426-431.

Massell, Benton F. 1969. "Price stabilization and welfare." *The Quarterly Journal of Economics*:284-298.

Miranda, Mario J, and Peter G Helmberger. 1988. "The effects of commodity price stabilization programs." *The American Economic Review*:46-58.

Muth, John F. 1961. "Rational expectations and the theory of price movements." *Econometrica: Journal of the Econometric Society*:315-335.

Newbery, David MG, and Joseph E Stiglitz. 1979. "The theory of commodity price stabilisation rules: Welfare impacts and supply responses." *The Economic Journal*:799-817.

Newbery, David MG, and Joseph E Stiglitz. 1982. "Optimal commodity stock-piling rules." *Oxford Economic Papers*:403-427.

Oi, Walter Y. 1961. "The desirability of price instability under perfect competition." *Econometrica: journal of the Econometric Society*:58-64.

Riethmuller, Paul, and Terry Roe. 1986. "Government intervention in commodity markets: the case of Japanese rice and wheat policy." *Journal of Policy Modeling* no. 8 (3):327-349.

Rozelle, Scott, and Jikun Huang. 2000. "Transition, development and the supply of wheat in China." *Australian Journal of Agricultural and Resource Economics* no. 44 (4):543-571.

Rozelle, Scott, Albert Park, Jikun Huang, and Hehui Jin. 2000. "Bureaucrat to entrepreneur: The changing role of the state in China's grain economy." *Economic Development and Cultural Change* no. 48 (2):227-252.

Samuelson, Paul A. 1971. "Stochastic speculative price." *Proceedings of the National Academy of Sciences* no. 68 (2):335-337.

Shea, Esther YP. 2010. "Understanding China's grain procurement policy from a perspective of optimization." *China Economic Review* no. 21 (4):639-649.

Sicular, Terry. 1995. "Redefining state, plan and market: China's reforms in agricultural commerce." *The China Quarterly* no. 144:1020-1046.

Srinivasan, PV, and Shikha Jha. 2001. "Liberalized trade and domestic price stability. The case of rice and wheat in India." *Journal of Development Economics* no. 65 (2):417-441.

Stiglitz, Joseph E. 1981. "The Theory of Commodity Price Stabilization." *Oxford: Oxford University Press. 'Optimal Commodity Stock-Piling Rules', Oxford Economic Papers* no. 34:403-27.

Thompson, Stanley R, Wolfgang Gohout, and Roland Herrmann. 2002. "CAP reforms in the 1990s and their price and welfare implications: the case of wheat." *Journal of agricultural economics* no. 53 (1):1-13.

Timmer, C Peter. 1989. "Food price policy: The rationale for government intervention." *Food Policy* no. 14 (1):17-27.

Turnovsky, Stephen J. 1974. "Price expectations and the welfare gains from price stabilization." *American Journal of Agricultural Economics* no. 56 (4):706-716.

Waugh, Frederick V. 1944. "Does the consumer benefit from price instability?" *The Quarterly Journal of Economics*:602-614.

Williams, Jeffrey C.., and Brian Wright. 1991. *Storage and commodity markets*: Cambridge University Press Cambridge.

Wogart, Jan Peter. 1983. "Combining price stabilization with trade and financial liberalization policies: The Argentine experience, 1976-1981." *Journal of Inter-American Studies and World Affairs*:445-476.

Yang, Jua, Xinkui Wang, and Hongzhou Geng. 2008. "Study on the effectiveness of government regulation of China's grain market: a case study of wheat." *Economic Research Journal* no. 8:005.

Zhou, Zhang Y, Guang H Wan, and Liang B Chen. 2000. "Integration of rice markets: the case of southern China." *Contemporary Economic Policy* no. 18 (1):95-106.

Zhuang, Renan, and Philip Abbott. 2007. "Price elasticities of key agricultural commodities in China." *China Economic Review* no. 18 (2):155-169.

Zwart, Anthony C, and KD Meilke. 1979. "The influence of domestic pricing policies and buffer stocks on price stability in the world wheat industry." *American Journal of Agricultural Economics* no. 61 (3):434-447.

CHAPTER 3 THE EFFECT OF REFRIGERATOR USE ON FOOD CONSUMPTION IN RURAL CHINA

3.1 Introduction

With income growth and technological progress, home infrastructure has been increasing quickly in developed countries (Bowden and Offer 1994), as well as in developing countries (McNeil and Letschert 2005). The refrigerator, as one of the key kitchen appliances, is expected to have an important effect in extending food life and improving people's standard of living. Owning refrigerators allows consumers to reduce food waste, reduce their frequencies of food purchasing from wet markets, and also encourages them to diversify their food purchase according to their preferences (Lyon and Durham 1999). Expanding refrigerator ownership in key markets, such as China, might lead to changes in food consumption patterns with consequences for local and global food and agricultural commodity markets.

In China, the government subsidized home appliance purchases of rural consumers. The level of the subsidy was 13% of the home appliance price. Since December 1, 2007, refrigerators, as well as televisions and mobile phones, were subsidized in Shandong, Henan and Sichuan Provinces. This policy was extended to 14 provinces since December 1, 2008, and launched countrywide on February 1, 2009. Over roughly the same period, the adoption of refrigerators in rural China increased, and the national average number of refrigerator owned per 100 households in rural China rose from 13.6 in 2000 to 45.2 in 2010 (Chinese Statistical Yearbook 2002 and 2011). In sharp contrast, 42.33% of urban households owned refrigerator in 1990, which suggests that the diffusion of refrigerators

in rural China lagged the pace in urban areas by 20 years (Chinese Statistical Yearbook 2011).

The question addressed here is how the expansion of rural refrigerator ownership affects household food consumption in China, with a specific focus on meat consumption. After rural residents of China own refrigerators, they can reduce food losses and waste, and might increase consumption demand for perishable goods, such as meat, seafood, and vegetables. If this is the case, then the transition from a low refrigerator ownership rate to a high ownership rate might be associated with price and income elasticity change of food demand. Researchers who ignore this effect might overestimate or underestimate food demand in the future. If the refrigerator ownership does matter, better prediction of rural food consumption can be performed in the long run by taking this factor into account, which is essential for policy makers to evaluate the supply and demand of grain.

This research question is of academic interest and also has business and policy implications. China is the country with the largest population, and it accounts for a significant share of global feed and livestock product markets----51% of total pork production and 11% of total beef production in 2014 FAS PSD data. Given the role of government subsidies in refrigerator ownership, impacts on meat and other food markets might be an unintended consequence. It is useful to know if consumers would in the future more readily buy meat or if their purchases will be more sensitive to income as a result of growing refrigerator ownership. Moreover, it could provide evidence for other developing countries regarding some of the benefits and costs to subsidizing refrigerator purchases.

The implications will be speculative until empirical tests of our hypothesis are complete. To address the problem, I review the literature on the topic, summarize relevant data, and present two methods to test the impact of refrigerators on food demand in rural China. The results indicate that refrigerator ownership reduced meat consumption, reduced total food expenditure, but significantly increased the expenditure share of meat, eggs, and seafood.

3.2 Literature Review

Food consumption in China has been the focus of many scholars and policy makers. Many scholars have found that China has great potential for income-driven meat demand growth, and will reduce direct grains consumption. Hsu, Chern, and Gale (2001) proposed that high income consumers would buy more meat, fruits, dairy products, and aquatic products, but less rice and grain compared to low income consumers. In addition, they found that seniors consumed more rice, fruits and vegetables, instead of meat or beer. Ortega, Holly Wang, and Eales (2009) analyzed meat demand using a linear approximation of an almost ideal demand system. Their results showed that pork elasticity with expect to group expenditure was less than one (0.86), while the expenditure elasticities for poultry and aggregated beef, mutton, and fish were greater than one (1.01 and 1.33, respectively).

In urban China, meat consumption has risen along with the income growth. For instance, Yen, Fang, and Su (2004) investigated household food consumption in urban China using a translog demand system and found that milk and most meat products were not only more price responsive than demand for other food, but also had high expenditure

elasticities. Zheng and Henneberry (2009) evaluated the economic and demographic effects on food consumption for grains, meats, poultry, aquatic products, dairy products, vegetables, and fruits based on urban household data from Jiangsu Province utilizing an almost ideal demand system (AIDS) model. Their results indicated that the demand for food of animal origins, such as meats, poultry, aquatic products, and dairy products, would increase by a larger magnitude compared to other foods as expenditure on these foods grew. They also found that demographic factors had a significant effect on food consumption. Zheng and Henneberry (2011) estimated an incomplete demand system over 2004 survey of consumption in urban areas of Jiangsu and argued that the majority of food demand categories for the low-income group was found to be less income and own price elastic, including meat, poultry. With the rising income after the reforms towards market-orientation in China, the demand for food away from home had been increasing sharply, paralleling by rapidly rising meat consumption, which could explain part of the apparent food stagnation in the late 1990s and potentially accounted for some of the inconsistency between China's livestock production and meat consumption data (Ma et al. 2006). Data representing at-home consumption of urban households in Guangdong province surveyed in 2007-2009 were used by Wu et al. (2014), who found that households with refrigerator will consume more powdered milk consumption. Bai et al. (2013) extended the at-home food use data by resurveying selected urban respondents and developing away-from-home food consumption. Estimating a quadratic almost idea demand system (QUAIDS) over these data led these authors to suggest that much higher expenditure affected meat consumption away from home more than at home for urban consumers.

A large part of the literature investigates the influencing factors and elasticities of the rural food consumption based on rural data in China. Halbrendt et al. (1994) analyzed consumer behaviors based on the rural Guangdong Household survey data. Their results indicated that most food commodities were not price elastic, and the substitution effect due to relative price changes were small, except for grains. However, in their results, meats, poultry, fruits, sweets, and durable goods were sensitive to expenditure change. Gao, Wailes, and Cramer (1996) estimated the effects of economic and demographic factors on China's rural household demand for nine food commodities in a two-stage demand system that combined an upper level AIDS and a lower-level generalized linear expenditure system as a modeling framework. Their results showed that slow rural demand growth for food in the latter half of 1980s originated from income stagnation rather than consumption saturation, and demand for high quality food and shelter would be priorities upon the future income increase. As income grew, consumers in rural China would consume more high quality and expensive foods, such as meats and dairy products (Yu and Abler 2009).

Some studies find that convenience and access to a market are also important factors on determining meat consumption. For example, market development in rural China was believed to be incomplete at the time of many studies, and this context might affect the demand for foodstuffs, in particular meat (Huang and Rozelle 1998). However, as the economy developed, supermarkets tended to replace central food markets, neighborhood stores, and street sellers of food in urban areas (Pingali 2007). Peng et al. (2005) conducted a survey in Shanghai and Nanjing for livestock consumption and found that

supermarkets and food store chains were the most important retail outlets for frozen and chilled livestock products, especially in large and mid-size cities.

From the above review, I conclude that the bulk of the literature studying food demand in China focuses on economic factors, like price and income, and a selection of demographic factors, such as household size, education level, and location. However, the effect of refrigerator ownership on food consumption was not widely studied, and the studies I have identified do not focus on meat demand in rural areas with a few exceptions.

Lyon and Durham (1999) included refrigerator ownership as factors for food demand quantity and expenditure, but they used urban data rather than rural data for the following reasons that they argued in the article. First, urban data were more extensive. Second, refrigerators had more important influence on urban food consumption because consumers were far away from the agricultural markets. In the study, price data were extrapolated from price indices. The authors used food quantity models and food expenditure models. The food quantity demand model included food prices, food at home expenditures, dining out expenditure, refrigerator ownership, and dummies for regions as explanatory variables. The own-price coefficients in all these models were negative and significant at the 5% level. The refrigerator ownership was estimated to have positive and significant effects on the quantity of meat and eggs consumed, and a statistically significant negative effect for grains. Expenditure models tested the effects of refrigerator ownership, income, and own price. Refrigerator ownership contributed to the egg and milk expenditure increase, the authors found, and caused grain expenditure to decrease

significantly. However, the authors found that refrigerator ownership had no significant effect for meat expenditure.

Gale (2005) used Working-Leser model, arguing that this model was relatively easy to estimate and had desirable properties that were reflected in households' budget share of each food group in rural China. The dependent variable was the share of expenditure, and the explanatory variables included per capita total expenditure and household characteristics, such as refrigerator owned, migrants working outside of the hometown, size of household, cultivated land area, family plot size, children under age 6, children age 6-15, and persons with senior high school education or higher. The model used household data from Heilongjiang, Henan, and Jiangsu Provinces for 1995 and 2001, which covered over 9,000 households in the three provinces each year. Six equations were used for cash food, noncash food, and nonfood expenditure share. Here, the noncash food was the food produced by farmers themselves. If the rural commodity market was not very complete, farmers consumed large quantities of goods that they produced within household. In contrast, cash food represented food purchased from the market by farmers and other consumers. These authors' results showed that refrigerator ownership had a positive effect on cash food expenditure share. Among cash food expenditure categories, refrigerator ownership had a positive effect on at home consumption of vegetables, meat and eggs, fish, other foods, and tobacco and alcohol, while it affected the budget share of grains and food away from home negatively. Based on the results, the author argued that households that owned refrigerators tended to allocate more of their budgets to cash food and less to noncash food expenditure, and spend more on perishable food. The drawback of the model is that they did not include any price data even though they argued that price

effect on food consumption in rural China was complicated because rural farmers in China were both producers and consumers. Ideally, prices should be included for an analysis of demand; if the agricultural products market was complete, all products could in principle be exchanged into income.

Given that previous research suggest an important effect of refrigerator ownership on consumer purchasing behaviors, and more specifically on meat demand, incorporating refrigerator use into demand analysis should be important for us to understand the China food market in the long run. In this research, my goal is to characterize the effect of refrigerator ownership on rural food consumption, particularly on meat. To achieve this goal, I test whether refrigerator ownership could affect food expenditure, or change food consumption pattern of rural people. In the next section, I summarize the data I use and apply two methods to test the impact of refrigerators on food consumption in China.

3.3 Data and Method

3.3.1 Data

This research uses panel data consisting of provincial level data for ten years, 2001 through 2010. Data are from the China Statistical Yearbook and China's Yearbook of Rural Household Survey, published by China National Statistics Bureau, as well as Yu and Abler (2009). The consumption data of each food group, the percentage of refrigerator ownership, and the per capita income are all from the China Statistical Yearbook. Food consumption refers to all the food consumed, including any food losses or waste. The price data in 2001 are from Yu and Abler (2009). Combining the food price in 2001, the price data in other years are computed based on the provincial level

consumer price index (CPI) for each food group. All nominal income data are converted into real values using rural China CPI based on the year 2001. I use annual aggregate data of different provinces from the household survey data that are widely used in research about China food consumption. This data set does not include away-from-home consumption. It is difficult to have an idea of how large away-from-home food consumption in rural China.

Table 28 Statistics summary of refrigerator ownership and major outcome variables

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Refrigerator Ownerships										
Mean	11.0	12.1	13.1	14.9	18.9	22.5	27.3	30.8	37.6	45.2
Medium	7.4	8.7	8.9	10.6	14.4	18.4	24.8	29.3	37.0	45.4
Std. Dev	9.6	10.0	10.9	11.8	13.3	15.1	16.3	16.4	17.3	17.8
Min	2.9	3.5	3.4	3.9	6.7	7.2	8.4	8.6	11.3	15.0
Max	46.6	48.6	53.1	56.6	66.5	71.4	78.3	83.4	88.9	92.3
Grain consumption per capita (Kg)										
Mean	239.1	238.6	222.5	218.4	209.5	206.6	200.2	199.2	188.9	181.9
Medium	236.1	233.4	224.0	218.0	207.3	204.0	197.0	192.2	187.0	177.6
Std. Dev	21.0	27.6	20.3	19.0	22.0	20.7	20.3	22.1	20.1	21.9
Min	205.4	201.6	193.3	189.7	175.0	166.9	159.1	166.4	153.3	142.9
Max	283.2	335.5	264.8	264.2	261.6	260.2	255.0	246.1	232.2	235.9
Meat consumption per capita (Kg)										
Mean	17.0	17.6	18.5	17.8	20.3	20.5	18.7	18.3	19.6	19.9
Medium	15.9	16.6	17.8	17.6	19.8	20.3	18.4	18.9	19.6	19.4
Std. Dev	7.1	7.0	8.2	7.8	8.3	8.5	8.0	7.8	8.3	8.0
Min	4.7	5.5	5.6	5.9	6.0	6.8	6.1	5.8	6.4	7.6
Max	31.2	30.5	32.7	32.9	36.0	35.3	32.7	32.8	33.8	34.3

Source: Chinese Statistical Yearbook (2002-2011), Chinese Yearbook of Rural Household Survey (2002-2011), summarized by authors.

From 2001 to 2010, the average refrigerator ownership rate among rural household increased from 11% to 45% (Table 1). Meanwhile, average grain consumption decreased from 239 kg per capita in 2001 to 182 kg per capita in 2010. Average meat consumption rose from 17 kg per person in 2001 to 20 kg per person in 2010. In addition, the ranges of refrigerator ownership, grain and meat consumption indicated by minimum and maximum values varied widely among provinces. For example, the lowest refrigerator

ownership in 2001 was 3% in Guangxi Province while the highest in that year was 47% in Zhejiang Province. The highest and lowest values were 92 % and 15% in 2010, respectively. The lowest level of meat consumption in 2001 was 5 kg per capita in Shanxi province, which rose to 8 kg in 2010. Meat consumption in Guangdong was the highest in 2001, with 31 kg, and in 2010, with 34kg. Most importantly, I can conclude that average levels of meat consumption varied widely among provinces in rural China.

Table 2 shows the variations among different provinces in meat consumption, refrigerator ownership, land size, and real income. The amounts of meat consumption spanned a wide spectrum among provinces. The average levels of meat consumption per capita were alike and exceeded 30 kg in Guangdong, Sichuan, and Yunnan Provinces, while the corresponding real incomes were 6664 yuan, 3962 yuan, and 3070 yuan in 2010, respectively. Although income levels were very different, meat consumption per capita was very close among these provinces, indicating that meat consumption might not be driven by income or at least not income alone. Moreover, higher income level and refrigerator ownership did not necessarily translate into higher meat consumption. In Hebei Province, the income level was high as compared to Sichuan and Yunnan and the refrigerator ownership was more than 50% in 2010, but Hebei meat consumption averaged lower than the other two provinces. Considering geography, the average meat consumption in Northern provinces were lower compared to Southern provinces, especially those in the southeast and southwest. As the major producing area of meat, southwestern China might have advantages of convenience and low price. In addition, large quantities of pork were produced by small households, who might consume the pork more as noncash food, as suggested by earlier studies. Yunnan had nearly the

highest meat consumption with the lowest income and refrigerator ownership rate, as well as small land average household area.

Table 29 Statistical summary of major variables by province

Provinces	meat consumption		Refrigerator ownership		Land size		Real income	
	Average	2010	Average	2010	Average	2010	Average	2010
Hebei	8.0	8.9	33.3	50.5	1.9	2.0	3390	4563
Shanxi	6.0	7.6	17.9	29.2	2.3	2.4	2714	3518
Inner Mongolia	25.3	28.1	20.6	42.8	8.3	9.7	2894	4147
Liaoning	18.9	18.4	32.7	58.7	3.3	3.5	3590	5094
Jilin	14.8	14.5	19.9	44.9	6.4	7.8	3257	4793
Heilongjiang	11.4	13.1	23.9	54.0	10.4	11.7	3237	4664
Jiangsu	14.1	20.4	28.8	59.3	1.6	1.1	2846	7190
Zhejiang	23.4	22.1	43.1	92.3	0.8	0.6	4491	9237
Anhui	16.9	15.1	16.5	63.3	1.5	1.9	3208	4248
Fujian	23.4	24.6	43.1	72.5	0.8	0.9	4491	6134
Jiangxi	16.9	16.9	16.5	45.8	1.5	1.6	3208	4651
Shandong	10.7	11.4	35.2	65.7	1.5	1.6	3919	5505
Henan	9.7	10.8	19.1	46.1	1.6	1.7	2916	4182
Hubei	21.8	21.5	21.9	51.5	1.5	1.7	3106	4406
Hunan	22.8	22.8	18.5	40.9	1.2	1.3	3014	4191
Guangdong	32.5	34.3	28.3	49.1	0.7	0.7	4849	6664
Guangxi	22.4	24.1	11.0	30.7	1.3	1.4	2571	3594
Hainan	26.1	29.9	8.6	15.0	1.1	1.3	2968	3898
Sichuan	31.8	33.0	19.6	49.4	1.0	1.1	2792	3962
Guizhou	28.8	27.5	10.7	27.2	1.1	1.1	1869	2632
Yunnan	30.8	34.3	8.0	18.2	1.4	1.5	2099	3070
ShannXi	7.5	8.3	11.6	27.0	1.8	1.9	2112	3138
Gansu	13.7	14.7	8.8	18.1	2.5	2.7	1903	2513
Qinghai	23.0	23.0	20.0	44.8	2.1	2.1	1982	2568
Ningxia	15.6	18.0	15.4	35.3	4.2	4.8	2498	3443
Xinjiang	13.6	14.8	23.8	43.5	4.1	4.8	2439	3359

Note: Average is the mean of value from 2001-2010; meat consumption is kg per capita each year; Land size is mu per capita; Real income is yuan per capita based on 2001; refrigerator ownership is the number of refrigerator every 100 household.
Source: Chinese Statistical Yearbook (2002-2011), Chinese Yearbook of Rural Household Survey (2002-2011)

Meanwhile, higher income is not necessarily associated with high refrigerator ownership rate. Real income per capita in 2010 was 3898 Yuan and 2593 Yuan for Hainan and

Gansu, while the refrigerator ownership was 15% and 18%. The land size per capita is diverse among different provinces. Households have more land in Heilongjiang, Jilin, Inner Mongolia, Ningxia, and Xinjiang compared to other provinces.

3.3.2 Method

I apply separately single demand equation and a demand system used to examine the effect of refrigerators on food consumption, particularly meat consumption, as outlined below. Both methods include economic and demographic explanatory variables, but the second approach imposes the more structured economic restrictions of a demand system. I apply two methods in order to (a) confirm the impact of refrigerator ownership on rural meat consumption and (b) trace out some possible explanations.

3.3.2.1 Demand equation

First, the relationship between meat consumption quantity and refrigerator ownership is estimated using three regressions, OLS, one-way fixed effect, and two-way fixed effect. The consumption of each food group is a function of its own price, substitute prices, income, and household characteristics such as household size, number of household laborers, average education level, house size, and arable land size, as well as refrigerator ownership rate. Given that food consumption is heterogeneous among provinces, there is enough variation that this method can estimate the effect of refrigerator ownership rate. The rest of heterogeneity among areas is explained by provincial fixed effects. Provincial fixed effect model can remove the effect of those time-invariant characteristics of each province, like habit and customs, and explore the relationship between the refrigerator

ownership and meat consumption within each province. Year fixed effect can control for impacts common to all groups but different by year, for instance, swine flu in 2007.

The household characteristics variables represent household size, the number of household laborers, the number of students per household, average education level, house size, and arable land size, as well as refrigerator ownership rate. Household size represents the average number of person in each family in different provinces. With bigger household size, the average individual meat consumption might be lower. Number of household laborers and number of students per household also represent the size of laborers and students. Average education level refers to the percentage of people with high school degree and above. Yu and Abler (2009) argued that households with higher education might plan to save more for the future education of children, so meat consumption might be lower for those families with higher education. House size might reflect the value of fixed assets. Household with higher house size might consume more meat. Arable land size is a control variable from supply side that might address the potential for endogeneity caused by meat supply response to price. Finally, the variable of interest is refrigerator ownership. With refrigerators, household might keep perishable food longer, reduce food waste, and reduce the frequencies of food purchase.

The estimated equations take the following form:

$$lnQ_{ijt} = \alpha + \beta_1 lnGRAINP_{jt} + \beta_2 lnFATOILP_{jt} + \beta_3 lnMEATP_{jt} + \beta_4 lnEGGP_{jt} + \beta_5 lnSEAFOODP_{jt} + \beta_6 lnVEGEP_{jt} + \beta_2 lnFRUITP_{jt} + \delta_1 lnRINC_{jt} + \varphi REFRI + \gamma_1 HHS_{jt} + \gamma_2 HHL_{jt} + \gamma_3 LS_{jt} + \gamma_4 EDUC_{jt} + \gamma_5 STUD_{jt} + \gamma_6 HS_{jt} + d_1 Dummy1 + d_2 Dummy2 + e_{ijt}$$

Where subscripts (i, j, t) represent food group, province, year, respectively; Q refers to the consumption of each food group; GRAINP, FATOILP, MEATP, EGGP, SEAFOODP, VEGEP, FRUITP are real prices of grain, fats and oil, meat, egg, seafood, vegetable, fruit; RINC is real rural income per capita; REFRI represents the number of refrigerator ownership per 100 household; and household characteristics include household size (HHS), household labor (HHL),the percentage of people with high school degree and above (EDUC), house size (HS), arable land size per household (LS), and students number per household (STUD). In addition, I have fixed effect of provinces and years, respectively.

3.3.2.2 Demand system

The QUAIDS model developed by Banks, Blundell, and Lewbel (1997) is applied in this study. As noted earlier, previous researchers had applied this model in China food demand analysis. Our model specification is as follows:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{x}{a(p)}\right) + \frac{\lambda_i}{b(p)} \left[\ln\left(\frac{x}{a(p)}\right)\right]^2 + t_i * trend + r_i * refri + \sum_{i=1}^{k} h_{ik} X_k + \varepsilon_i,$$

Where subscripts i and j indicate the studied food groups (grain, fats and oils, meat, eggs, seafood, vegetables, fruits). X represents household characteristics: household size (HHS), the percentage of people with high school degree and above (EDUC), arable land size per household (LS), students per household (STUD), the number of household members in labor market (HHL), and house size (HS). Thus, there are 6 elements in X; k is from 1 to 6. The refrigerator variable is the number of refrigerators owned per 100 household.

The non-linear QUAIDS price index a(p) is defined as

$$\ln(a(p)) =$$

$$\alpha_0 + \sum_j(\alpha_i + t_i * trend + r_i * refri + \sum_{i=1}^{k} h_{ik}X_k)lnp_j + \frac{1}{2}\sum_j \sum_i \gamma_{ij}\, lnp_i lnp_j \ .$$

b(p) is the Cobb-Douglas price aggregator and is defined as:

$$b(p) = \prod_{i=1}^{n} p_i^{\beta_i}.$$

The adding-up restrictions are imposed as:

$$\sum_i^n \alpha_i = 1; \sum_i^n \beta_i = 0; \sum_i^n \gamma_{ij} = 0; \sum_i^n \lambda_i = 0; \sum_i^n t_i = 0; \sum_i^n r_i = 0; \sum_i^n h_{ik} = 0.$$

Homogeneity is imposed as: $\sum_j^n \gamma_{ij} = 0$ for any j. The Slutsky symmetry restriction is $\gamma_{ij} = \gamma_{ji}$ for any i and j.

The price and expenditure elasticities are calculated from the estimated parameters of QUAIDS system following Banks, Blundell, and Lewbel (1997). The uncompensated (Marshallian) price elasticities are:

$$e_{ij} = w_i^{-1}\left\{\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{b(p)}\right)\left[ln\left(\frac{x}{a(p)}\right)\right]\left(\alpha_j + \sum_{k=1}^{n}\gamma_{jk}\ln(p_k)\right) - \frac{\lambda_i\beta_j}{b(p)}\left[\ln\left(\frac{x}{a(p)}\right)\right]^2\right\} - \delta_{ij}$$

Where δ_{ij} is the Kronecker delta, which is equal to 1 when $i = j$, otherwise $\delta_{ij} = 0$. The food expenditure elasticities are calculated as:

$$e_i = 1 + w_i^{-1}\left[\beta_i + \frac{2\lambda_i}{b(p)}\ln\left(\frac{x}{a(p)}\right)\right].$$

In addition, the refrigerator expenditure might have effect on food expenditure and food expenditure might have the problem of endogeneity. So I add an expenditure equation to explain food expenditure variations as a function of the price of these goods, income, and demographic variables. This equation is

$$\ln(x) = \varphi_0 + \varphi_1 * a(p) + \varphi_2 * \ln(inc) + \varphi_3 * (\ln(inc))^2 + \varphi_4 * trend + \varphi_5 * refri + \sum_{i=1}^{k} h_{ik}X_k.$$

3.4 Results

3.4.1 Results of fixed effect model

3.4.1.1 Model Test

Both groups of independent data, food prices and household characteristics, have a high possibility of multicollinearity. Consequently, a multicollinearity test is used to select significant variables for the model. After the test, vegetable price, income squared, household labor, student ratio are not included in the single meat demand regression. Income and refrigerator ownership do not have severe multicollinearity, so it might not

be inefficient in the estimates of parameters caused by keeping both these variables in the regression.

The null hypothesis of the Hausman test is that there are no systematic differences in the coefficients of fixed effect model and random effect model. According to the Hausman Test results in Table 3, the null hypothesis can be rejected at the 1% level. Thus, although several estimation results are shown, I use two way fixed effects (columns labeled “FE (II)” in the table) to estimate the parameters of the model.

3.4.1.2 Regression Results

I estimate the single demand equation with OLS, one-way fixed effect, two-way fixed effect, and show the results in Table 3. Compared to OLS regressions, two-way fixed effect models has high adjusted R-square, up to 0.97, indicating that fixed-effect model can explain rural meat consumption in China very well. The fixed effect approach generates uniformly smaller estimates for the parameters of own-price, income, and refrigerator ownership compared to OLS regression. At least two explanations for the difference between the OLS and fixed effect estimates exist. First, each province has its own specific characteristics, such as land resources, climate, water resources, and culture. Cultural differences, in particular, might include general preferences for foods eaten at home. Second, the government policies vary a lot among provinces from east to west. For instance, reforms that began in 1978 started with the provinces in eastern part of China, along the coast.

In the first set of regressions, through three estimates with different treatments of fixed and random effect, I find a negative and statistically significant effect of refrigerator ownership on meat consumption in rural areas. There are several findings to draw from the main results that are from the two-way fixed effect model in column 4. First, the entry in the fourth column of Table 3 indicates that a 1% increase in the ownership of refrigerator every 100 household is associated with 1kg decrease in meat consumption in rural areas. Second, the rural meat demand equation estimates indicate a sizable, negative effect of meat price on meat consumption. This negative coefficient demonstrates that meat is responsive to own-price change, and this result is consistent with the findings of previous studies. Third, income has the statistically significant and positive effect on meat consumption. The strong income impact on meat consumption is in line with previous findings (Yu and Abler, 2009). Fourth, meat demand substitutes with seafood, as shown by the positive coefficients on prices of seafood. Meat demand is complementary with grain, fat and oil, eggs, and vegetables, as all the coefficients on these food prices were negative. Finally, the demographic factors also have the significant effect on meat consumption. The coefficient of education level is -0.01, which is significant at the 5% level. Finally, as noted earlier, the estimated impact of refrigerator ownership is negative, if assessed using the negative and statistically significant coefficient of column 4.

Table 30 Regressions results of meat consumption with different equations

Independent Variables	OLS	FE (I)	FE(II)
Ln(Grain Price)	-0.58	-0.03	-0.36
	(0.10)***	(0.13)	(0.18)**
Ln(Fatoil Price)	0.42	-0.01	-0.17
	(0.09)***	(0.08)	(0.10)
Ln(Meat Price)	-0.71	-0.10	-0.23
	(0.11)***	(0.09)***	(0.16)
Ln(Egg price)	0.89	-0.33	-0.04
	(0.12)***	(0.13)	(0.17)
Ln(Seafood Price)	0.05	0.26	0.10
	(0.06)	(0.15)***	(0.16)
Ln(Fruit Price)	-0.16	-0.23	-0.30
	(0.07)**	(0.08)	(0.08)***
Ln(Real Income)	1.35	0.32	0.53
	(0.13)***	(0.13)***	(0.19)***
Refrigerator Ownership	-0.01	-0.002	-0.003
	(0.00)***	(0.001)	(0.001)**
Household Size	0.08	-0.47	-0.27
	(0.05)	(0.10)***	(0.09)***
House Size	-0.01	0.01	0.00
	(0.00)***	(0.01)*	(0.00)
Education	-0.03	-0.002	-0.01
	(0.00)***	(0.004)	(0.00)**
Constant	-6.58	2.67	1.62
	(0.87)***	(1.09)**	(1.78)
Adjusted R-square	0.66	0.96	0.97
Province Dummy		Yes	Yes
Year Dummy		No	Yes
Hausman Test		690.65	690.65
		(P<.0001)	(P<.0001)
Observations	260	260	260

Note: *** denotes significance at the 1% level, **denotes significance at the 5% level, and * denotes significance at the 10% level.

Source: estimated by authors.

3.4.2 Demand system results

In the estimation of a QUAIDS model representing food demand in rural China, the food expenditure share of each food group is the function of its own price, cross prices, real expenditure and real expenditure squared, refrigerator ownership, and demographic characteristics. To allow for the endogeneity of expenditure, an expenditure equation is constructed as an auxiliary equation, and is explained by the demand system price index, real income, real income squared, refrigerator ownership, time trend, and demographic variables.

Table 4 shows the estimation results of QUAIDS model and the expenditure equation. The results about the effects of refrigerator ownership on group expenditure share and total expenditure are interesting. First, the refrigerator ownership has the positive effect on the expenditure share of meat, egg, and seafood, and negative effect on those of grain and fruits. These findings are consistent with my speculation that people consumed more perishable food, like meat, seafood, and less nonperishable food, like grain. Second, refrigerator ownership has statistically significant and negative effect on total food expenditure, and the parameter is -0.01. This indicates that owning refrigerators causes consumers to reduce their total food expenditure.

Moreover, other results from QUAIDS model are worth noting. First, food expenditure and expenditure squared have statistically significant effects on the expenditure share of meat, egg, seafood, and fruits. Second, the expenditure shares of grain and the fat and oil group are sensitive to own-price changes, but others are not, if assessed strictly based on statistical significance. Third, demographic characteristics, like household size, education level, and house size, have statistically significant effects on the expenditure shares of grains, meat, eggs, and vegetables.

In addition, there are also some findings from the estimated results of the expenditure equation. First, the price index has a statistically significant and positive effect on food expenditure. If one or more food prices go up, consumers can adjust and increase total food expenditure. Second, income and income squared do not have statistically significant effects on food expenditure, and their parameters are positive and negative, respectively. With income growth, consumers' food expenditure first increases and then

decreases. Third, household characteristics, like household size, education level, and house size, all have statistically significant effects on food expenditure. The bigger the household size is, the less the food expenditure per capita is. Those big families might have economies of scale for food consumption, and per capita consumption may be lower. It is also possible that big family have to expend more on other good and reduce the food expenditure. In addition, education level has a negative effect on food expenditure. Moreover, house size has a positive effect on food expenditure. House size might represent the level of fixed assets which might bring about higher purchasing power.

Table 5 reports the Marshallian Elasticities and Hicksian Elasticities, as well as expenditure elasticity. The Marshallian own-price elasticities of egg and seafood are the first and second most elastic, while those of fat and oil and fruit are the first and second least elastic. The Marshallian own-price elasticities of grains, meat, vegetable are -0.39, -0.49, and -0.34, respectively. The expenditure elasticity of seafood is the highest, followed by egg elasticity, fat and oil elasticity, and meat elasticity, while grains, fruits, and vegetables expenditures elasticities are the smallest.

Table 31 Summary of estimated coefficients of QUAIDS model and expenditure equation

Explanatory variables	Coefficients of grain	Fat and oil	meat	Egg	seafood	vegetable	Expenditure
Ln(Grain Price)	0.17 (0.04)***						
Ln(Fat and oil Price)	-0.03 (0.01)***	0.03 (0.01)***					
Ln(Meat Price)	-0.16 (0.04)***	0.01 (0.02)	0.07 (0.10)				
Ln(Egg price)	-0.00 (0.02)	0.00 (0.01)	0.03 (0.02)**	-0.02 (0.01)			
Ln(Seafood Price)	0.02 (0.04)	-0.02 (0.02)	0.09 (0.05)**	-0.02 (0.02)	-0.06 (0.04)		
Ln(Vegetable Price)	0.03 (0.05)	-0.00 (0.02)	0.05 (0.07)**	-0.02 (0.03)	-0.08 (0.02)***	-0.01 (0.08)	
Ln(Fruit Price)	-0.02 (0.01)***	0.01 (0.00)***	-0.01 (0.01)	0.01 (0.00)***	-0.00 (0.00)	-0.00 (0.00)	
Ln(Expd)	0.07 (0.08)	0.02 (0.04)	0.17 (0.09)*	0.06 (0.03)*	-0.13 (0.05)***	-0.19 (0.06)***	
Ln(Expd squared)	-0.01 (0.01)*	-0.00 (0.00)	-0.01 (0.01)*	-0.00 (0.00)	0.01 (0.00)***	0.01 (0.00)***	
Price index							0.28 (0.05)***
Ln(Income)							0.78 (0.78)
Ln(Income squared)							-0.00 (0.05)
Refrigerator ownership	-0.001 (0.00)**	0.00 (0.00)	0.001 (0.00)*	0.0003 (0.00)***	0.0006 (0.00)***	-0.001 (0.00)***	-0.01 (0.00)***
Household Size	0.03 (0.01)***	-0.00 (0.00)	-0.08 (0.01)***	-0.01 (0.00)***	0.00 (0.00)	0.05 (0.00)***	-0.19 (0.03)***
Education Level	0.00 (0.00)***	0.00 (0.00)	-0.01 (0.00)***	0.00 (0.00)***	-0.00 (0.00)	0.002 (0.00)***	-0.01 (0.00)***
House Size	-0.00 (0.00)	0.00 (0.00)	-0.001 (0.00)*	-0.002 (0.00)***	0.001 (0.00)***	0.002 (0.00)***	0.01 (0.00)***

Note: *** denotes significance at the 1% level, **denotes significance at the 5% level, and * denotes significance at the 10% level. *Expd* represents expenditure.

Source: estimated by the author.

Table 32 Demand elasticity estimated by QUAIDS model with refrigerator ownership

	Grain	Fat & oil	Meat	Egg	Seafood	Vegetable	Fruit
Marshallian Elasticity							
Grain	-0.39	-0.08	-0.28	0.02	-0.05	0.01	-0.04
Fat and oil	-0.96	-0.08	0.02	0.24	0.27	-0.45	-0.33
Meat	-0.41	0.01	-0.49	0.01	0.05	-0.19	-0.04
Egg	-0.12	0.23	-0.07	-1.30	-0.11	-0.53	0.28
Seafood	-0.93	0.23	0.13	-0.12	-0.86	-0.30	-0.18
Vegetable	-0.01	-0.09	-0.34	-0.09	-0.03	-0.34	0.02
Fruit	-0.37	-0.26	-0.24	0.26	-0.11	0.06	-0.19
Hicksian Elasticity							
Grain	-0.09	-0.05	-0.02	0.05	-0.02	0.14	-0.01
Fat and oil	-0.49	-0.04	0.44	0.29	0.32	-0.25	-0.27
Meat	-0.02	0.05	-0.15	0.05	0.09	-0.03	0.01
Egg	0.47	0.29	0.45	-1.24	-0.05	-0.27	0.35
Seafood	-0.19	0.31	0.78	-0.05	-0.78	0.02	-0.09
Vegetable	0.32	-0.06	-0.05	-0.06	0.00	-0.20	0.05
Fruit	-0.06	-0.23	0.04	0.29	-0.08	0.20	-0.15
Expenditure Elasticity							
	0.82	1.29	1.06	1.62	2.04	0.89	0.85

Source: estimated by the author.

Table 6 compares the elasticity results with and without considering refrigerator ownership in the QUAIDS and the expenditure equation. If the model does not consider refrigerator ownership, then the price elasticities of meat, as well as its expenditure elasticity are estimated to be higher (in absolute value). In other words, the model without considering refrigerator ownership might overestimate the price and expenditure elasticity. This might lead to higher predicted levels of meat demand with income growth in the future. In addition, the own-price elasticity of grain, fat and oil, egg, and fruit appear to be underestimated. The expenditure elasticity of fat and oil, egg, seafood, and vegetable might be underestimated while that of grains and fruits tends to be overestimated.

Table 33 Change in demand elasticity estimates (with refrigerator ownership – without refrigerator ownership)

	Grain	Fat & oil	Meat	Egg	Seafood	Vegetable	Fruit
Marshallian Elasticity							
Grain	0.06	-0.01	0.01	-0.03	-0.02	0.02	0.01
Fat and oil	-0.17	0.01	-0.01	0.08	0.05	-0.04	-0.01
Meat	0.02	0.00	-0.04	0.00	0.03	0.05	0.00
Egg	-0.32	0.08	-0.06	0.37	0.08	-0.11	-0.11
Seafood	-0.34	0.04	0.18	0.07	0.00	-0.19	-0.05
Vegetable	-0.02	-0.01	0.03	-0.03	-0.04	-0.09	0.00
Fruit	0.13	0.00	0.02	-0.09	-0.03	0.04	0.02
Hicksian Elasticity							
Grain	0.04	-0.01	-0.01	-0.03	-0.02	0.02	0.01
Fat and oil	-0.13	0.01	0.02	0.08	0.06	-0.03	-0.01
Meat	-0.01	0.00	-0.06	0.00	0.03	0.04	0.00
Egg	-0.29	0.08	-0.04	0.38	0.08	-0.10	-0.11
Seafood	-0.23	0.05	0.27	0.08	0.01	-0.14	-0.03
Vegetable	0.04	-0.01	0.08	-0.02	-0.03	-0.06	0.01
Fruit	0.10	-0.01	-0.01	-0.09	-0.03	0.02	0.02
Expenditure Elasticity							
	-0.04	0.09	-0.08	0.07	0.29	0.17	-0.10

Source: estimated by the author.

3.5 Discussion

3.5.1 Refrigerator ownership

One contribution of this study to the literature is that it provides empirical evidence of at least the short-run effect of refrigerator ownership on food consumption, especially meat. Here, meat consumption is defined as consumption quantity, including food waste, rather than purchase quantity. Based on the estimation results of the single demand equation, refrigerator has statistically significant and negative effect on meat consumption quantity. Meanwhile, according to the results of QUAIDS model and the expenditure equation, refrigerator ownership has a statistically significant and positive effect on meat expenditure share, as well as egg and seafood, while using refrigerator reduces the expenditure share of grains and vegetables. Most intriguingly, the negative effect of refrigerator ownership on meat consumption in the single demand equation is consistent

with the negative effect of refrigerator ownership on total food expenditure in the expenditure equation. Taking all the findings together, refrigerator ownership might help reduce food expenditure and meat consumption quantity, although meat expenditure share increases. There are several possible explanations. First and most importantly, using refrigerators might reduce the food losses and waste, especially after the food is purchased from market, because consumers have a better way to store their food. For instance, it might be the case that they cook more food than they need for each meal, perhaps because of a preference for over-supplying food at meal time or with the intention of cooking extra to have left over food for later consumption. In either case, the surplus food is more likely to spoil without refrigerators, resulting in the food being thrown away or fed to livestock or poultry. After households have refrigerators, they can keep food fresh for longer and reduce food waste, leading to lower apparent consumption. Second, consumers might reduce their frequencies of food purchase and make better meal plans. When they have to buy food for family every day or every other day, they might buy more than they needed randomly, which can also lead to some food losses or waste. Third, consumers might adjust their habit or patterns to consume more perishable foods and less nonperishable food. When consumers do not have refrigerators or other good ways to store food, they may have to depend greatly on nonperishable food.

This result for meat demand in rural areas is opposite to the findings of the previous research (Lyon and Durham 1999). From the results of QUAIDS estimation, refrigerator ownership has significant and positive effect on meat expenditure share in rural areas, which is consistent with the finding of a positive impact on meat expenditure demonstrated by Gale (2005). The previous studies are not entirely comparable with the

present study, however. Lyon and Durham (1999) focused on urban consumers and there is no overlap between their data period and the 2001-2010 period that I use for this study. The regional focus of this study and Gale (2005) overlap, but their data ended in 2001 which is when my data started. Perhaps more fundamentally, neither study used actual food or commodity price data in their estimation.

3.5.2 Price and expenditure elasticities

Another important contribution of this study is that it demonstrates the overestimation of the price elasticity and expenditure elasticity without considering refrigerator ownership in the estimation model. The coefficients of real income are all statistically significant, from both the single demand equation and the quadratic demand system, which emphasizes that income or expenditure plays an important role in determining the growth in meat consumption in rural China. However, omitting refrigerator ownership from the demand system can bias the 2010 meat income elasticity upward by 7%, which will lead to overestimating the prediction of future meat demand in rural China. The results from this study might encourage researchers to think about whether China's food elasticities used by international organizations, such as OECD, World Bank, FAO, and USDA are reliable.

3.5.3 Demographic factors

The estimation results of single demand equation suggest that demographic factors play an important role in explaining meat consumption in rural areas, especially household size and education level. Per capita meat consumption in big household may be smaller compared to smaller family. Moreover, household size, house size, education level have the significant effect on the expenditure share of grain, meat, egg, seafood and vegetable.

Also, household characteristics have the significant effect on the total food expenditure. This indicates that total food expenditure is not only related to price and income, but also highly associated with demographic factors. These are consistent with previous studies.

3.6 Conclusions

This study finds that rising refrigerator ownership in rural China might reduce meat consumption and total food expenditure, at least in this period, while it might increase the expenditure share of meat, egg, seafood, and reduce the expenditure share of grains, vegetables. These results indicate that market assessments based on recent quantities, prices, and demographic characteristics that do not take rising refrigerator ownership risk overstating the role of income and perhaps overestimating the underlying demand. These findings should be of interest to Chinese policy makers who chose to subsidize refrigerator purchases, and who might not be aware of the effects of refrigerator ownership on food expenditure and consumption. These findings are also relevant for agribusinesses that assessed the meat market potential of rural China now and in the future.

The results are robust for two different approaches that are applied. One is a more statistics-driven approach that imposes no theoretical constraints on parameters or structure. The second approach imposes more restrictions based on economic theory. Nevertheless, there are limitations. First, data limitations disallow any assessment of the refrigerator effect on away-from-home meat consumption, at this time. Second, as noted earlier, there are always concerns relating to data quality and practical matters in estimation, such as reliable price data.

The finding that refrigerator usage has negative impacts on food expenditure and meat demand quantity in rural China over the period 2001-2010 could be a cause for concern. The average number of refrigerators per hundred households was less than 50 at present in 2010 in rural China, and still rising. Rising refrigerator ownership might help to shape the broader commodity markets, including supplies, prices, and trade, in the future. The implications for China's domestic food and farm policies, China's trade profile, and global markets could be relevant to public and private decision makers.

REFERENCES

Bai, Junfei, James L Seale, Thomas Wahl, and Bryan Lohmar. 2013. Meat demand analysis in urban China: To include or not to include meat away from home? : Paper presented at the Agricultural and Applied Economics Association's 2013 AAEA and CAES Joint Annual Meeting, Washington, DC.

Banks, James, Richard Blundell, and Arthur Lewbel. 1997. "Quadratic Engel curves and consumer demand." *Review of Economics and Statistics* 79 (4):527-539.

Bowden, Sue, and Avner Offer. 1994. "Household appliances and the use of time: the United States and Britain since the 1920s1." *The Economic History Review* 47 (4):725-748.

Gale, H Frederick. 2005. "Commercialization of food consumption in rural China." *USDA-ERS Economic Research Report* (8).

Gao, XM, Eric J Wailes, and Gail L Cramer. 1996. "A two-stage rural household demand analysis: Microdata evidence from Jiangsu Province, China." *American Journal of Agricultural Economics* 78 (3):604-613.

Halbrendt, Catherine, Conrado Gempesaw, Dimphna Dolk-Etz, and Francis Tuan. 1994. "Rural Chinese food consumption: the case of Guangdong." *American Journal of Agricultural Economics* 76 (4):794-799.

Hsu, Hsin-Hui, W Chern, and Fred Gale. 2001. "How will rising income affect the structure of food demand?" *China's Food and Agriculture: Issues for the 21st Century*:10-13.

Huang, Jikun, and Scott Rozelle. 1998. "Market development and food demand in rural China." *China Economic Review* 9 (1):25-45.

Lyon, Carmi A, and Catherine A Durham. 1999. "Refrigeration and Food Demand in China Can refrigerator ownership help predict consumption of food products in China?" *In: Chinese Agriculture and the WTO, Proceedings of the WCC-101, 2–3 December*:47.

Ma, Hengyun, Jikun Huang, Frank Fuller, and Scott Rozelle. 2006. "Getting rich and eating out: consumption of food away from home in urban China." *Canadian Journal of Agricultural Economics* 54 (1):101-119.

McNeil, Michael A, and Virginie E Letschert. 2005. "Forecasting electricity demand in developing countries: A study of household income and appliance ownership." *European Council for an Energy Efficient Economy-2005 Summer Study. Mandelieu, France. LBNL-58283*.

Ortega, David L, H Holly Wang, and James S Eales. 2009. "Meat demand in China." *China Agricultural Economic Review* 1 (4):410-419.

Peng, Xuehua, Mary A Marchant, Xiang Dong Qin, and Jun Zhuang. 2005. "Chinese consumers' preferences for livestock products." *International Food and Agribusiness Management Review* 8 (4):62-76.

Pingali, Prabhu. 2007. "Westernization of Asian diets and the transformation of food systems: implications for research and policy." *Food policy* 32 (3):281-298.

Wu, Beibei, Yongfu Chen, Wei Si, and Hsiaoping Chien. 2014. "A Double-Hurdle Analysis of Demand for Powdered Milk: Evidence from Household Survey Data in an Urban Chinese Province." *Agribusiness* 30 (3):331-344.

Yen, Steven T, Cheng Fang, and Shew-Jiuan Su. 2004. "Household food demand in urban China: a censored system approach." *Journal of Comparative Economics* 32 (3):564-585.

Yu, Xiaohua, and David Abler. 2009. "The demand for food quality in rural China." *American Journal of Agricultural Economics* 91 (1):57-69.

Zheng, Zhihao, and Shida Rastegari Henneberry. 2009. "An analysis of food demand in China: a case study of urban households in Jiangsu province." *Applied Economic Perspectives and Policy* 31 (4):873-893.

Zheng, Zhihao, and Shida Rastegari Henneberry. 2011. "Household food demand by income category: evidence from household survey data in an urban Chinese province." *Agribusiness* 27 (1):99-113.

Vita

Jing Zhao was born in Laiyang, Shandong Province, China. Jing was very interested in international trade, especially agricultural products, which led her to China Agricultural University, where she studied International Economics and Trade. With excellent achievement in undergraduate period, she obtained the admission to enter the master program of international trade without examination. When Jing was a master student in China Agricultural University, she met several professors from Food and Agriculture Policy Research Institute (FAPRI). With a strong interest in food and agricultural policy, she decided to apply for the doctoral program at the Department of Agricultural & Applied Economics at the University of Missouri, and fortunately she got the opportunity to pursue her doctoral degree at MU with a special assistantship. From 2010 to 2013, she was very lucky to work as an intern at IHS Global Insight, where she learned a lot from team members.

Jing is married to Xiaobin Gao in 2012, who received his PhD degree in Genetics from Yale in May 2015. They have a lovely daughter, Agnes. In their spare time, they learn together and play together.