UNDERSTANDING CHINESE FARMERS' GRAIN STORAGE

by

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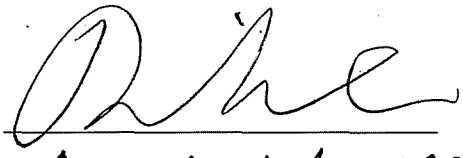
Signature 

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ABSTRACT

China is the largest grain producer and consumer in the world. Since introducing its open-door policy in the 1980's, China has become an increasingly important grain importing country. However, China's wheat imports have varied considerably from year to year. One key issue affecting China's grain imports is its large on-farm grain reserves. This thesis is intended to examine factors significant for China's on-farm grain stocks and shed some additional light on its potential impacts on China's domestic grain markets and grain import activities.

The key finding is that Chinese farmers' grain supply is primarily from self-production. The Chinese government decrees that farmers be not eligible to purchase grain from government food agencies that control 70 to 80 percent of the total marketed surplus of grain in China. This policy plus the underdeveloped domestic grain and credit markets leads Chinese farmers to store a considerable amount of grain for consumption.

The food- and income-security concern of Chinese farmers is found to be another important factor in Chinese farmers' grain storage decisions. The highly variable weather, a still developing infrastructure, and frequent changes in government grain policies all increase the risk faced by Chinese farmers, thus increase their food- and income-security concerns. This thesis finds that the increasing number of farm family members working off-farm can help reduce the quantity of on-farm grain storage because of the potential remittance from more stable off-farm earnings to the farm home. It is also found that farmers tend to store less as income increases due to changes in absolute risk-aversions of farmers.

The last important finding of thesis is that Chinese farmers' grain storage is somewhat price-elastic, in contrast with suggestions by some Chinese economists that China's on-farm grain storage is primarily for food-security concerns and therefore generally price-inelastic. It is also found that additions to farm household grain storage is directly elastic with respect to household grain output.

CHAPTER 1

INTRODUCTION

China is the largest grain producer and consumer in the world. Since introducing its open-door policy in the 1980's, China has become an increasingly important grain importing country. In most years of the 1990's, China's wheat imports have been quite substantial, accounting for almost 8 percent of total world wheat exports during the period 1990-1998. However, China's wheat imports have varied considerably from year to year, reaching a record high of 15.4 million metric tons (roughly 14 percent of total world imports) in 1991, but falling to only 2 million metric tons in 1997. One key issue affecting China's grain imports is its unusually large on-farm grain reserves (Crook, 1996). This thesis is intended to examine factors significant for China's on-farm grain stocks and shed some additional light on its potential impacts on China's domestic grain markets and grain import activities.

China's grain storage can be classified into three categories: state strategic reserves, local government working stocks, and on-farm grain stocks held by farmers. The first two function mainly as buffer stocks to stabilize grain prices in the domestic market. On-farm grain storage comprises half of the country's total grain storage and may affect domestic grain markets in unpredictable ways. To date, little concrete research has been carried out on this issue due to the lack of transparency in China's agricultural policy and the difficulty in obtaining pertinent data. However, some general explanations

for Chinese farmers' grain storage—such as food security considerations, poor transportation systems, and credit market imperfections have been considered (Ke, 1996).

China's grain policy has varied from complete control of production and distribution to the current system permitting considerable freedom on grain production and marketing. Prior to 1979, China's grain production was carried out on collectively through production teams (Watson, 1988). Individual production was strictly prohibited. Those production teams were also ordered to deliver a certain amount of grain (the government procurement quota) to the government upon harvest at a price much lower than market price. Government food agencies (grain bureaus) then distributed grain among urban residents through a coupon rationing system.

An important feature of this distribution policy that still survives is that farmers are not eligible to purchase grain from grain bureaus which control 70 to 80 percent of the total marketed grain surplus in China (Crook, 1996). Farmers are expected to consume self-produced grain. This administratively stipulated grain self-sufficiency of farmers produces a major rationale for on-farm grain storage in China.

In 1979, in response to the inefficiency of collective production, the government replaced it with a "Household Responsibility System" in the rural reform launched in 1979 (Lin, 1994). The new system contracted land, farm equipment, and government procurement quotas (the meaning of "responsibility" in the "Household Responsibility System") to individual households. Farmers were allowed more freedom in grain production and marketing. But they were also required to deliver the government procurement quota they contracted. Failure to fulfill the quota could result in severe cash penalties. The "Household Responsibility System" immediately demonstrated much

greater efficiency in grain production and became the dominant production form in China (Lin, 1994).

Prior to the 1979 rural reforms, the grain marketing system was also tightly controlled by the government. Grain bureaus took the dominant role in grain marketing. Farmers were prohibited from trading grain in the market (Watson, 1988). After 1979, controls on free grain markets were gradually loosened, and farmers were allowed to trade their grain in free markets. Towards the end of 1992, the Chinese government began to implement an ambitious plan aimed to completely deregulate the grain market. Restrictions on entrants to the grain market were removed (People Daily, 1998). The attempt was ill-fated and shortly stopped because of the sharp increase in grain prices in urban areas and resulting complaints and protests from urban residents.

Chen, (1994) has suggested that by late 1993, the grain market remained regionally segmented. Bureaucratic obstacles, regional blockades, and entry barriers were common. In addition, local grain markets were still usually closed by the government for approximately one month during the procurement period. Under these constraints, farmers were unwilling to rely on the free market for their food supply, increasing on-farm grain storage.

Agricultural production in China is risky because of highly variable weather, a still developing infrastructure, and frequently changing government policies. Given this risk, grain storage allows flexibility in sales, promotes stability of income, and may serve as a hedge against hyperinflation (Johnson and Song, 1998).

This thesis derives a two-period household utility maximization model to analyze Chinese farmers' on-farm grain storage, consumption, and market sales. Factors that may

potentially influence grain storage are identified, including total grain output, the government procurement quota, the market price, quota revenue, and demographic information. Conditions for positive storage are also derived.

The empirical analysis of grain storage is conducted using household survey data recorded on farms in Northeastern China in 1994. This data set includes information on wheat storage, consumption, harvest, price, and other variables. Farmers' wheat storage, consumption, and market sales decisions are modeled and estimated by seemingly unrelated estimation techniques.

Results of the empirical analysis strongly suggest that wheat from self-production remains a major source of farmers' food supply. One interesting result is the number of family members working or living off-farm significantly reduces wheat storage. This result provides support for the hypothesis that storage is linked with food- and income-security because the potential from monetary remittances from off-farm family members adds stability to the farm income, reducing household income risk.

Wheat storage is found to be directly related to output and it is elastic. This result suggests that China's grain or credit markets or both are still not mature. Wheat storage may provide a save mechanism for Chinese farmers. Another important finding is that farmers' wheat storage is price-elastic. This result contrasts Ke's (1996) suggestion that Chinese farmers store grain primarily for food-security motives. Finally, household wheat supplies are found to be more responsive to the change in wheat output than change in price factors.

Chapter 2 of this thesis describes the grain reserve system of China and Chinese grain policies during the period from 1953 to 1998. Chapter 3 discusses potential factors

influencing Chinese farmers' grain storage. Chapter 4 lays out the theoretical model for Chinese farmers' grain storage. Chapter 5 reports the empirical analysis of on-farm storage among selected villages in Northeastern China. Summaries and conclusions are provided in Chapter 6.

CHAPTER 2

STOCKS, POLICY & GOVERNMENT GRAIN PROCUREMENT SYSTEM IN CHINA

Classification of Chinese Grain Stocks

China's grain reserve system is quite complex. Storage can be divided into three categories. The first category includes grain stocks held on the farm by farm families. Chinese farmers had a long tradition of storing grain due to China's highly varied grain production. For a typical five-year period, historically, there has been approximately two bumper crop years, two disastrous years, and one average year (Crook, 1996).

After the establishment of People's Republic of China (P.R.C.) in 1949, the government decreed that farmers should not be eligible to buy grain from government food agencies, which controlled about 70 to 80 percent of total marketed surplus. Farmers were also obliged to deliver a fixed amount of grain upon harvest to the government, for which they were paid an administratively determined price that was lower than the market price (Lin, 1994).

Local private grain markets were often poorly functioning. These markets were sometimes even prohibited, particularly during the quota delivery period. In addition, given that China's transportation system is underdeveloped, the transportation cost to purchase grain from the private market was considerably high (Lardy, 1990). Grain markets were therefore not reliable sources for farmers' food supply. For these reasons,

on-farm storage was an important component for farmers' food supply. Farm level grain storage continued to increase after 1949, but remains difficult to assess. Chinese economists estimated that total on-farm grain storage in China was about 90 million tons in 1996 but this number is only abut one-half or one-third the level estimated by western economists (Crook, 1996).

The second category of grain stocks are those held by various levels of local governments. These grain stocks began to be established in early 1950's and were meant to stabilize local grain markets and provide food assistance to local areas suffering natural disasters. In the 1990's, the national government required that grain surplus provinces store enough grain to satisfy at least three months of consumption and that grain deficit provinces should store enough grain to satisfy at least six months of consumption. However, these storage requirements have not been met by most provincial governments (Crook, 1996). It is also difficult to move grain between provinces in China, discussed in more detail later in this chapter.

Third, state strategic grain reserve is controlled by the State Administration of Grain Reserves (SAGR). The SAGR grain reserve was established in 1990 when a bumper grain harvest caused serious difficulties for farmers to sell grain. The national government therefore decided to buy tens of millions of tons of grain from farmers at a "protection price" which was higher than the prevailing market price, and to establish a strategic grain reserve directly controlled by the national government. The purpose of the SAGR grain reserve was to add stability to nationwide grain markets, to protect farmers' incentives to produce grain by supporting the grain price via government purchasing, and to strengthen the ability of the national government to transfer grain between provinces.

In 1990, there were only four out of thirty provinces (autonomous zones) that were able to ship surplus grain to other provinces (Crook, 1996). One reason is the vast land area of China and an underdeveloped transportation system. For example, in 1983, one main grain-producing region, Yanbei Prefecture in Shanxi Province signed contracts with Beijing, Tianjin, Hunan, and Guangxi provinces to sell its bumper grain output. The contracts were not fulfilled because the railway authority decided to assign its limited railway capacity to moving coal out of the province (Lardy, 1990).

High transportation costs, bureaucratic obstacles, local short-term interests, and rent seeking behavior are fundamental factors hindering interprovincial grain transfer (Lardy, 1990). During the period of 1949 to1986, the national government was responsible for transferring grain from surplus provinces to deficit provinces. The transfer price received by the shipper was the fixed quota price provided by the deficit province plus a special subsidy provided by the national finance department. However, the purchasing price received by the grain bureaus in surplus regions from the national government did not cover the price they paid for procurement from their subordinate counties plus their operational costs (Lardy, 1990). The more grain these provinces transferred, the greater the financial loss, dampening incentives of interprovincial grain transfer.

After 1986, the national government gradually reduced its role in interprovincial grain trades. Deficit and surplus provinces were allowed to trade grain and negotiate directly. At the same time, government food processing units were not guaranteed grain supplies; instead, they were required to purchase grain in the grain market. Although the national government dictated that local governments should not restrict grain sales to

outside areas, local bureaucrats, driven by local short-term interests or rent-seeking motives, often ignored this requirement (Chen, 1994). Therefore, a strong national strategic grain reserve was deemed necessary to balance the national grain market.

China's Grain Policies During 1949-1978

Shortly after the foundation of P.R.C. in 1949, farmers were organized into production teams, a type of production cooperative under communist principles. Production was conducted on a collective basis and all farm production materials—including machinery, seed, and fertilizer—belong to the production team (Watson, 1988). Individual members received bonus points based on their attendance, efforts, and skills. At the end of the year, they received different dividends according to the bonus points they had earned during the year. No individual production was allowed. Production teams were assigned land to grow grain and other cash crops under government plans. Although the terminology has changed over years, the production-team was, in fact, the only production form before the rural reforms of the 1970's.

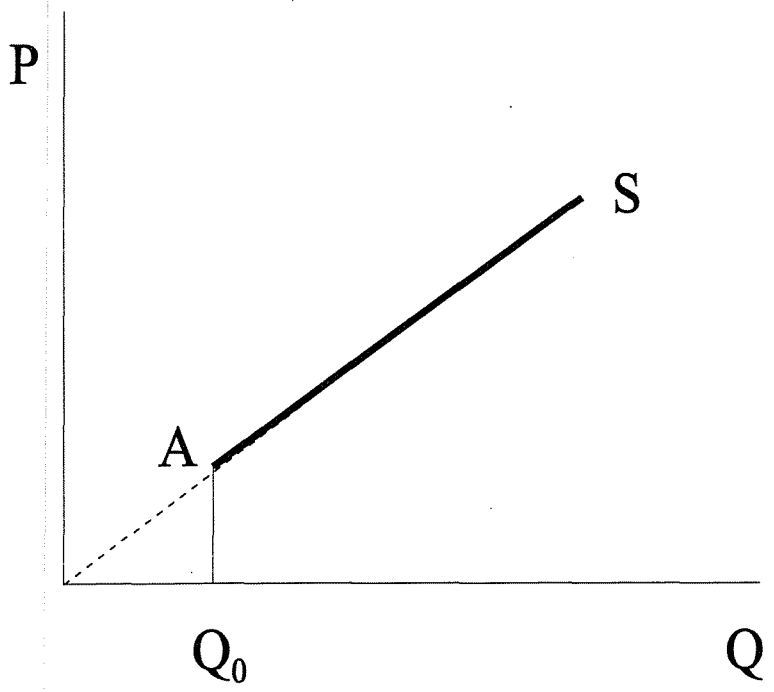
The government grain procurement system was introduced in 1953. At that time, Chinese leaders felt that China was in a disadvantageous situation because of confrontations with the former Soviet Union and the United States. Food security was a major concern (Watson, 1988). The procurement program was introduced to achieve complete control over the supply and distribution of grain. After harvest, production teams were required to deliver specific amounts of grain at a fixed price. This price was below the price farmers would have received in an open market. The government then

distributed grain to permanent urban residents through a coupon rationing system. Government Grain bureaus took charge of both grain procurement from farmers and distribution to urban residents. Private grain marketing was strictly restricted in order to ensure the success of the government procurement program.

In 1960's, the national government introduced an over-quota procurement system with the purpose of encouraging agricultural production. It stipulated that after fulfilling the fixed-price quota delivery, farmers could sell grain to the government at premium prices, about 30 percent over prices for mandatory quota delivery. Despite minor revisement and nominal changes, the core elements of this program have survived to the present.

Figure 1 illustrates the effects of the government quota on farmers' grain supply since the establishment of the P.R.C. First, farmers must deliver Q_0 amount of grain quota to the government. The quota is effectively enforced and farmers seldom fail to delivery it. Therefore, farmers' real grain supply curve starts at point A on their supply curve S.

Figure 1: Effects of The Government Quota on Farmers' Grain Supply



Rural Reforms 1978-1984

After the death of Chairman Mao Zedong in 1976, his successors began to focus on the shortcomings of China's economic development over the previous two decades. These shortcomings were quite clear when China's economic development was compared with neighboring East Asian countries such as Japan, Singapore, and Korea. (Watson, 1988) New leaders were eager to carry out economic reforms in the hope of increasing production and consumption goods. Rural reform was selected prior to urban reform because its implementation was considered to be easier. The reform was launched in 1978, at the Third Plenary of the 11th Communist Party of China (CPC) Central

Committee. Three main decisions made at that meeting dramatically affected grain producers:

First, due to the difficulty in monitoring individual members' performance in a team agricultural production, compensation had not been fully tied to performance. The team production form provided little incentive for individual members to work hard. Shirking was widespread and output was low (Lin, 1994). In the late 1970's, although not officially permitted, voluntary household contract-production began to replace the team production in some areas. Procurement quotas, production materials, and land were all contracted among members of the production team. This contract-production form almost immediately resulted in greater productivity and increased farmer income. However, government authorities were initially reluctant to provide public support for this contract-production form because it was deemed contradictory to communist principles. After three years, the national government officially recognized this practice and promoted it to the whole country as the "Household Responsibility System". However, adoption of the Household Responsibility System was slow due to different opinions among national leaders and did not become universal until 1984.

Second, the government increased the quota procurement price (Lin 1994). Since the quota price had been set lower than the prevailing market price (even for the premium price), the more farmers sold to the government, the greater loss they suffered. Therefore, farmers were reluctant to increase grain production and sales. The government increased procurement prices after 1978, with the average quota price for grain increasing by 20 percent. The over-quota premium price for grain was also increased accordingly.

Third, the government reduced its role in the grain marketing system. Realizing that over-extensive planning had caused inefficiency in resource allocation, the government reduced the number of agricultural items included in its planning list (Lin, 1994). In addition, grain quotas were reduced and restrictions on open grain markets (rural grain fairs) were loosened.

The consequences of these reforms were substantial. Gross value of agricultural output increased at an annual rate of 7.5 percent between 1980 and 1982 and an annual average rate of 13 percent between 1982 and 1986, much higher than the 4.3 percent average growth rate a year over the period 1971-1978 (Chinese State Statistical Bureau, 1986).

Reforms after 1985

Increased grain output, while a indicator of the success of rural reform, imposed a heavy burden on the government budget since the government increased the purchase price of grain from farmers but did not increase the retail price for urban residents. The retail price was actually lower than the cost of grains purchased by government plus transportation and operational costs (Lin, 1994). The resulting losses from urban subsidies were solely borne by the National Finance Department. Due to the price increase of the procurement program, losses associated with grain procurement and subsidized sales rose from about 3.5 billion Yuan in 1978, to 18.3 billion Yuan in 1983, and about 24 billion Yuan in 1985 (Lin, 1994). The government tried to lower the real purchase price of grain in 1984 by introducing a purchasing contract (with lower purchasing prices) to replace mandatory procurement quotas in order to reduce the

financial burden. This resulted in the stagnation of grain output from 1985 to 1988. In 1988 and 1989, the government raised the grain procurement prices to high levels. As a result, China's grain producing achieved a new record highs in 1990 and 1991 (Lin, 1994).

Attempt of Market Liberalization in 1993-1994 and Its Retreat

Between 1990 and 1998, the market-oriented economy had already been widely adopted in China for many other goods, many provinces began to try to liberalize grain markets. The 1993-1994 national grain reform also attempted to reduce national government budget outlay for grain. Grain bureaus at all levels had accumulated a debt of about 50 billion Yuan by the end of 1992 (Findlay and Watson, 1998). The finance department charged that grain bureaus disguised some of their commercial loss under the title of policy-induced loss. The central authority finally stipulated that all debts of grain bureaus before 1992 were classified as policy-induced debts and that finance department would write off these debts. Beginning in 1993, grain bureaus were to become independent, commercially profitable food enterprises. At the same time, other competitors, including private grain merchants, were allowed to enter the grain market to compete with government grain bureaus (Findlay and Watson, 1998).

By the early 1994, ninety percent of Chinese counties deregulated their grain markets (People Daily, 1998). Among these counties, the price of grain increased sharply at the end of 1993 in urban areas, resulting in fierce complaints from urban residents. There were several reasons for these price increases (Crook, 1996). These included: (1) an approximate 21.8 percent increase in average input prices; (2) a 12 percent increase in

real income of urban residents; and (3) grain bureaus were under more pressure to maximize their profits. However, ensuring sufficient low-priced food supplies for urban residents has long been and remains the primary concern of Chinese grain policy (Crook, 1996). Turmoil in food markets was the last thing that Chinese policy makers wanted to see. The national government responded to the food price increases by releasing about 20 million tons of national strategic grain reserve supplies to dampen price increases and also launched other policies such as price ceilings for both grain and production inputs. These policy activities worked effectively to ease the grain price. However, they also marked the retreat for the biggest official move since 1985 to create a more open and integrated grain market in China.

The Current Chinese Grain Policy

In the aftermath of the grain market crisis, the national government decided to resume its intervention in the grain market. Policy makers decided to maintain the annual procurement of 90 million metric tons of grain, between 70 and 80 percent of the total marketed surplus (Crook, 1996). Of this 90 million tons, 50 million would be purchased at the quota procurement price and 40 million at the premium or market price. Market entrance by buyers was again restricted and private grain merchants were prohibited from dealing directly with farmers. At the same time, the national government launched a new grain marketing system called the "Governor Responsibility System" the main feature was provincial level governments were charged with the responsibility to ensure food self-sufficiency for their own provinces.

Shortly after this new responsibility system was launched, the grain market experienced another large fluctuation. A bumper harvest in 1995 pushed the grain market to the other extreme. Grain prices fell sharply with average grain price plunged as low as 30 percent (People Daily, 1998). Farmers' incentives to grow grain were seriously reduced. Meanwhile, grain bureaus at all levels of government were losing money at a more rapid rate because they were required to purchase surplus production as prices above the new market cleaning prices. Total losses experienced by grain bureaus accumulated to 19.7 billion Yuan (2.4 billion U.S. dollars) in 1996 and 48 billion Yuan (5.8 billion U.S. dollars) in 1997.

At the same time, corruption among grain procurement officials were widespread. An investigation suggested that the value of total government grain reserves in stock was worth only one-half the grain procurement costs (People Daily, 1998). A large part of the fund paid by the government had been pocketed by grain procurement officials.

Thus, in June, 1998, the national government changed its grain policy again. The policy changes in this period reflected the same intention of 1993-1994 reform, but were carried out in a less radical way. Again, the main attempt was to push grain bureaus to become commercially independent enterprises with losses limited to only those that were policy-induced by the government (People Daily, 1998). But in contrast to the emission of 1993-1994 reform, grain bureaus were given local monopoly power to purchase and market grains. The national government forced grain bureaus' competitors out of the grain market to help grain bureaus reduce losses and increase profits.

Three principles were embedded in the latest reforms. First, entry into the grain market by private merchants during the post-harvest procurement period was prohibited.

The government grain bureau was the only legal party who could purchase and market grain during the period. Second, grain bureaus were to be responsible for their own losses or profits. They would receive no subsidies from the national government unless the loss was policy-induced. Third, grain bureaus were required to buy whatever quantities of grain that farmers were willing to sell. Prices were to be determined according to grain quality. Losses incurred by unusually excessive procurement levels (in unusual bumper crop years) would be borne by the national government.

The retreat from the 1993-1994 reform and the current Chinese grain policy reflected the dilemma of the national government in choosing between the incentives to farmers, consumer price stability, and large policy-induced losses. China's economic reform started in rural areas in 1978. Since then, the reform has been extended to the industrial sector. However, the grain market is still regulated tightly by the government. This suggests that the stability of food markets is still a vital part of Chinese leaders' agenda and complete grain market reform is still forthcoming.

In summary, Chinese farmers have historically experienced wide output and price variability. After the foundation of People's Republic of China, they were continuously forced to deliver government grain quotas at low prices and faced considerable dramatic swings in policy. At the same time, free grain markets are not well developed and often intervened by government agencies. Grain markets, have not functioned as the reliable source of food supply for farmers. Credit markets are also imperfect. Grain stocks, useful as insurance against crop failure, as a hedge against high inflation and as a storage of wealth, continue to be of the utmost importance to Chinese farmers.

CHAPTER 3

FACTORS INFLUENCING CHINESE FARMERS' GRAIN STORAGE

This chapter will briefly discuss previous research about storage issues and potential factors specifically influencing Chinese farmers' grain storage. Storage of agricultural commodities allows allocation of consumption over time. Buffer stocks, both held privately and by governments, are considered important tools to stabilize prices of agricultural products (Newbery and Stiglitz, 1981).

Storage in developed countries is addressed in Gardner (1978), Newbery and Stiglitz (1981) and Williams and Wright (1991). This body of work focuses on welfare maximizing effects of grain stocks and incentives for private storage. An important conclusion of these studies is that private storage will tend to decrease with large public stocks, because expected price increases will be reduced by the release of public stocks (Williams and Wright, 1991; Newbery and Stiglitz, 1981). Gardner (1979) gave four general factors that influence private storage decisions:

1. How storage affects the current marginal utility of the storer, determined by his utility function. By carrying grain over to the next period, storers must sacrifice current grain consumption or benefits from grain sales. Different tastes and preferences and income will lead to different marginal utilities foregone and thus, different level of storage.

2. The expected price of grain in the next period and how this expectation is formed. Absent other considerations, storage will not occur unless the storer expects the discounted price in the next period to be at least as high as the current price.

3. The interest rate, because storers can simply sell the grain today and deposit the money into the bank and obtain interest revenue, the interest rate determines the magnitude of the intertemporal opportunity cost of storage.

4. Storage cost, including physical and a quality loss. In addition, storage gives rise to other costs such as building and maintaining storage facilities. Transaction costs foregone from storing grain must also be considered. Suppose that a farmer does not store grain, but instead, sells all of his output. When he needs food, he buys it from the market, giving rise to certain transaction costs arising from transportation cost, sales and opportunity costs of time. The transactions cost avoided by holding grain storage can be viewed as a convenience yield (Renkow, 1990). More broadly and probably more properly, the convenience yield should include not only the transaction cost avoided by holding grain storage but also all other storage-induced benefits, particularly food and income security provided for storers. Thus, the storage cost should be the physical cost of storage deducting this convenience yield. The final storage cost could be either positive or negative, depending on the magnitude of physical storage costs and convenience yield.

Considering the above four factors, storage is justified for an optimal expected value only if the sum of the discounted expected price increase and the convenience yield

is no less than all the costs incurred. In short, the above condition for positive storage can be expressed as following:

(1) $$\varphi E[\tilde{P}_1] + CY \geq P_0 + IR + C$$

where φ denotes the discount scalar of time. The expected price of next period is denoted by $E(\tilde{P}_1)$ and the convenience yield is denoted by CY. The term P_0 denotes the current price and interest revenue foregone is denoted by IR. The storage cost is denoted by C.

An important factor closely related to the convenience yield is the risk involved in storage activities. Risk plays an active part in grain production. Weather, pests, and crop diseases are unpredictable. Volatile output results in volatile grain prices. The price in the next period may decrease or increase, and grain holders could either lose or make money.

Two attitudes toward risk are widely adopted in the storage literature. One is risk-neutrality. If two options have the same expected return, risk-neutral producers are indifferent between a riskier and a safer option. (Newbery and Stiglitz, 1981). Alternatively, risk-averse producers prefer an alternative with a lower variance to an alternative with a higher variance when both have equal expected returns. The amount producers are willing to sacrifice from the expected value of a risky return to get a sure return is called the risk premium. Therefore, storers' attitudes toward risk (risk-aversion or risk-neutrality) should be treated as part of the convenience yield. It is widely held that farmers in less developed countries (LDCs) are risk averse (Newbery and Stiglitz, 1981). Empirical research on household grain storage of an Indian village demonstrated risk-aversion of farmers driven by food- and income-security concerns (Saha and Stroud, 1994).

The same research also suggested that the lower household income is the greater that household's concerns about food-security. Therefore, it is likely that risk-aversion for farmers is greater in developing countries than in developed countries. The convenience yield from storage (food- and income-security), in turn, could be more important in decisions about storage in developing countries than in developed countries under this assumption.

Food- and income-security concerns stem mainly from two factors. One is uncertain output. When farmers experience a short crop year, if the food market is not well functioning (the market access is restricted or the market price is prohibitively expensive), they may face extreme hardship. The other factor is the uncertain market price. When the market price decreases considerably, they may have lower incomes from crop sales.

Grain storage in China is somewhat different from other countries. The Chinese government's grain policy requires that farmers should be responsible for their own food. They are not eligible to buy grain from grain bureaus, the government agency in charge of grain distribution. This policy requires farmers to meet their food consumption during the entire period between harvests, encouraging storage of a large amount of grain. Some regions can harvest a staple crop twice or three times per year, while others can harvest only once. These different harvest schedules, in a large part, explain the substantial differences in grain storage levels among regions (Crook, 1992).

The government procurement quota program precludes private grain merchants from purchasing and marketing grain during the post-harvest period. Subsequently, farmers can sell as much grain as they desire to grain bureaus at a premium price after

they fulfill their procurement quotas. As a result, free markets for grain are, at least to some extent, distorted. In addition, government policies change frequently, and grain dealers must absorb the resulting high risks and accompanying high opportunity costs. These distortions and unreliability adversely affect the efficiency of grain markets in China.

Although the national grain policy promises farmers that they will be able to sell as much grain as they want to the government, local grain bureaus do not always carry out this policy. In the early 1990's, China's grain bureaus had to bear increasing responsibility for their own profits or losses. When it is not profitable to procure grain at the favorable procurement price, local grain bureaus are reluctant to buy grain from farmers. Even if they can not openly refuse to buy farmers' grain, they use various indirect methods to dampen farmers' selling. These practices include increasing the quality requirement of procured grain, purposely prolonging the procurement process, and issuing IOUs instead of cash. The resulting increased transaction costs lead some farmers to choose to store their grain and sell to private grain merchants after the procurement period when the free grain market is open again, rather than selling to the government.

Another factor possibly resulting in China's unusually large on-farm grain stocks is hyperinflation during the period of 1980 to 1990's. Johnson and Song (1998) suggest that grain stocks serve at least two main functions for Chinese farmers. One is as insurance against income shocks caused by crop failure, illness and inability to work. The other is as a hedge against inflation. Grain stocks, due to their ability to be readily marketed and because they are key consumption goods, are preferred assets for such

purposes. Their attractiveness is further enhanced by China's imperfect credit markets and the government's prohibition of private land ownership. Hyperinflation often led to negative real interests during the period of 1980-1990's and official nominal interests adjusted slowly. In the presence of a potentially negative real interest rate and possibly limited financial services in rural areas, grain stocks are more attractive than saving deposits for farmers.

Johnson and Song's empirical analysis suggests that grain stocks adjusted with changes in economic conditions. They found that the real grain price was linked with farmers' expected inflation rate through the change of stocks. When inflation is expected to be high, farmers tend to increase their stocks and thus their marketed surplus falls. As a result, the aggregate market supply decreased and the free market price is pushed up. Johnson and Song conclude that the expected inflation (deflation) significantly affects grain stocks held by Chinese farmers. They further suggest that a stabilized price against high inflation would reduce the incentive of farmers to store grain and thus reduce the quantity of on-farm grain stocks.

The widespread use of IOUs in the government procurement process also affects farmers' storage decisions and sales. Local grain officials often divert grain procurement funds issued by the national government to other purposes for a period and then pay farmers (Johnson and Song, 1998). It is not uncommon for farmers to receive payment for as months after delivery without any foregone interest compensation. These IOU's reduced the intertemporal opportunity cost of storage and may have a positive effect on the quantity of storage.

An important reason for grain storage by Chinese farmers, food security, was not added by Johnson and Song. A survey conducted by Ke (1996) indicated that most farmers stored grain because of fear of crop failure and that only 20 to 30 percent of the on-farm storage was sensitive to price. In addition, farms in the same areas fear that floods could destroy access to timely food supplies from sources outside their region.

Even if transportation could be assured, grain markets are still likely to be unreliable. From the 1950's until rural reforms of 1978, grain was prohibited from entering local markets. Farmers, classified as rural residents by the government, were not eligible to buy grain from government grain bureaus. After 1978, private rural commodity markets began to reappear. Commodities like vegetables and meat, which did not fall within the government procurement list, could be traded freely. The development of free markets was slower for agricultural products, such as grain, were under strict control of the government. Not until 1986 did some traditional grain marketing center like Wuxi and Zhenjiang begin to reemerge (Watson, 1988). Yu and Zhou (1995) showed that peasants sold their surplus grain through six key channels: the local free market; small private grain traders; grain bureaus; supply and marketing cooperatives; the government's foreign trade department; and commercial and industrial users. Grain sold to small grain traders and grain bureaus and supply and marketing cooperatives is then resold in wholesale markets. Small grain traders form the first stage in the marketing system. In most cases, they sell their grain to larger private grain merchants. These small traders can also sell grain to grain bureaus or industrial users.

Grain bureaus and supply and marketing cooperatives normally sell grain directly to the wholesale market. Because small private grain merchants can sell grain onward to

state grain bureaus, there is potential for rent-seeking and corrupt behavior by government grain agencies and officials. Grain bureau officials have incentives to set obstacles for farmers to sell grain at the premium price, and then to send their representatives to act as private grain traders and purchase grain from farmers at a lower price. Finally, these representatives can sell grain to grain bureaus absent obstacles and capture the price difference (Chen, 1994).

Wholesale grain markets in China are also not sufficiently developed. According to Chen (1994), there were two national grain markets by the end of 1993, Zheng Zhou and Shang Hai, ten province level regional wholesale grain markets, less than one hundred small regional wholesale markets, and about 80,000 local grain markets. Chen concluded that the free grain market system was not nationally integrated in China. The market was segmented and did not play a dominant role in the grain marketing. If this is true, the free grain market may not be a stable source for farmers' food supply. Grain stocks are therefore still an effective way for farmers to meet their food security needs if government food aid is not considered. For farmers living in areas in which transportation conditions are not convenient, or those who really understand an urban bias of the government (thus do not give much hope for the government aid), grain stocks are their only insurance against bad crop year.

As for factors influencing food security of farmers, Crook (1996) has suggested annual harvests played an important part. The probability of crop failure in Southern China is much lower than in Northern China because areas in Southern China can harvest staple crops two to three times a year. In the contrast, normally there is only one staple

crop harvest in Northern China. As a result, per capita grain storage in Southern China is much less than that in Northern China.

Apart from output variability, the government procurement quota may also play a role in farmers' grain stock decisions. The quota has at least two effects on the household grain storage. First, the existence of quota decreases grain availability for storage because each year farmers are forced to deliver a fixed amount of grain to the government. Second, since failure to deliver the quota would result in severe cash penalties and the quota delivery is effectively enforced, farmers would tend to store more than if this quota did not exist due to food- and income-security concerns. In order to determine the effects of quota on households' grain stocks, income levels must be considered. Research by Saha and Stroud (1994) indicated that farmers with higher incomes in India tend to be less risk averse for food-security concerns.

In summary, based on previous research work, consumption and the food and income security concerns appear to be the two biggest motives for Chinese farmers to store grain. First, they are not eligible to buy food from government agencies (grain bureaus) and are supposed to consume self-produced grain. Second, local grain markets are segmented and may not be reliable. Grain markets could be segmented at county level. Different counties set their own rules for the grain market. If a crop failure occurs and farmers try to get access into grain markets in neighboring counties, they could meet various bureaucratic obstacles, high transportation costs, higher opportunity cost of time and possibly higher grain prices. Therefore, the free grain market is not currently a viable option for Chinese farmers to supply food grain.

If grain stocks are driven primarily by food security concerns, they will not be very price-sensitive. Historically, when government procurement prices increased, output also increased. Stocks, however, often increased at the same time. This suggests that farmers tend to increase their output while not reducing the storage when prices are high. Speculative motives for grain storage are probably less important for Chinese farmers. Including interest forgone, the physical costs of storage and the loss of quantity and quality of the stored product, the annual cost of storage ranges from 15 to 20 percent of the value of the stored grain (Johnson and Song, 1998). Speculative motives of price improvement themselves can hardly explain farmers' continuous large amount of on-farm storage.

CHAPTER 4

THEORETICAL FRAMEWORK

This chapter presents a theoretical model for Chinese farmers' decisions with respect to grain storage, grain consumption, market sales of grain, and borrowing and lending. The theoretical framework developed in this chapter provides the rationale for the econometric models presented in the next chapter. This thesis extends a time-invariant additively separable utility maximization model derived by Saha and Stroud (1994) by including the Chinese government's procurement quota, an important component in China's grain policy. Farmers face substantial penalties if they fail to fill their quota and the penalties are effectively enforced. Including the quota in a more detailed model provides useful insights about Chinese farmers' storage activities.

The model of the farm household's decisions on market sales of grain, grain consumption, storage, and borrowing and lending is structured as follows: The farm household produces a single staple food and consumes a large part of its harvest. The surplus will be either sold (to the government or to free markets or both), or put into storage. The farm household is concerned with maximizing the discounted present value of the expected utility in two periods, period 0 and period 1. In period 0, the farm is assumed to already harvest its crop prior to its optimization decision. In period 1, its crop harvest is unknown. In that period, the expected output is a function of inputs, but the actual output depends on realized yield which is stochastic because of uncertainties of

weather, pest conditions, and other stochastic production elements. The household utility in a given period depends on household grain consumption, c, and the consumption of a numeraire good, y. The numeraire good represents household consumption of all other commodities and is normalized by household income as the grain consumption is assumed to come out of household grain production and household grain storage. In period 0, household consumption of grain and household income are non-stochastic because the crop harvested is already known. In period 1, because crop production is unknown, full household income is unknown, thus, the objective function for the farm is as follows:

$$U(c_0, y_0) + \varphi E\left[U(c_1, y_1)\right] \tag{2}$$

where U (·) is a twice differentiable utility function. The term φ is the discount scalar of time. The expectation operator for this uncertain production in period 1 is denoted by E [·]. The farm's utility maximization problem is constrained by household income and grain consumption in period 0 and period 1. The household income in period 0 is defined through equation (3):

$$y_0 = P_{q0} \cdot \bar{q}_0 + P_{f0} \cdot q_{f0} + b_0 - t(s_0 + \Delta s_0) \tag{3}$$

where the government procurement quota is denoted by $\bar{q}_0$ and the quantity of grain sold on the free market by the household is denoted by q_{f0}. The term P_{q0} represents the price paid for grain delivered under the government quota and P_{f0} denotes

the free market price of grain. Borrowing by the household in period 0 is denoted by b_0. Its sign is negative if the household is a lender.

The term s_0 denotes the initial storage endowment in period 0 and Δs_0 denotes the change in household grain storage. The net storage cost in period 0 is denoted by t ($\Delta s_0 + s_0$). Net storage costs have two components (Renkow,1990). One is the physical cost of the storage, the other is the convenience yield, i.e. the storage-induced reduction of transaction costs of selling and buying food grain. Therefore, net storage costs could be either positive or negative. A negative net storage cost means that the convenience yield is greater than the physical cost of storage and vice versa. Finally, the price of all other goods, y_0, is normalized to unity.

The consumption constraint in period 0 is defined through Equation (4):

4) $$c_0 = Q_0 - q_{f0} - \bar{q}_0 - \Delta s_0$$

where farm output is known and defined by Q_0.

The income constraint in period 1 is defined through Equation (5):

(5) $$y_1 = P_{q1} \cdot \bar{q}_1 + P_{f1} \cdot q_{f1} - a_1' \cdot Z_1 - (1+r)b_0$$

where Z_1 denotes a vector of inputs including on-farm labor and off-farm family labor and a_1 denotes a vector of input prices including the labor wage rate. Thus, the input costs of period 1 is denoted by $a_1' \bullet Z_1$. When the household is a net labor supplier (hirer), its off-farm family labor supplied is more (less) than its on-farm hired labor demanded and the labor input in Z_1 is negative (positive). Off-farm earnings are an importance source of farm revenue through remittances. The farm household must pay off all debts, b_0, in period 1 with an interest r.

The consumption constraint in period 1 is defined through equation (6):

$$c_1 = Q(Z_1, \varepsilon) - q_{f1} - \bar{q}_1 + (s_0 + \Delta s_0) \tag{6}$$

where the output Q (•) in period 1 is a function of inputs Z_1 and a risk term ε. The term ε represents some uncertain factors such as weather which affect the yield. Since it is a two-period problem, the household does not reserve grain stocks in period 1, using up wheat carry-over stocks from period 0.

The farm household's optimization problem in period 0 can thus be represented as follows:

$$\underset{x_0}{Max}\ H = U(Q_0 - q_{f0} - \Delta s_0, P_{q0} \bullet \bar{q}_0 + P_{f0} \bullet q_{f0} + b_0 - t(\Delta s_0 = s_0)) + \tag{7}$$

$$\varphi E\left[U(Q(Z_1, \varepsilon) - q_{f1} - \bar{q}_1 + \Delta s_0 + s_0, P_{q1} \cdot \bar{q}_1 + P_{f1} \cdot q_{f1} - \alpha_1' \cdot Z_1 - (1+r)b_0) \right]$$

where $X_0 = \{q_{f0}, \Delta s_0, b_0\}$ and equations (3), (4), (5) and (6) have been substituted into the objective function, equation (2). Consumption is also a derivable variable, but it is defined through the constraints in equation (4). Assuming that interior solutions exist, the first order conditions for the choice variables in period 0 yield:

$$H_{q_{f0}} = -U_{c_0} + P_{f0} U_{y_0} = 0 \tag{8a}$$

$$H_{\Delta s_0} = -U_{c_0} - U_{y_0} t_{\Delta s_0} + \varphi E[U_{c_1}] = 0 \tag{8b}$$

$$H_{b_0} = U_{y_0} - \varphi(1+r) E[U_{y_1}] = 0 \tag{8c}$$

The first order conditions yield some useful results. First, the marginal rate of substitution between the consumption of grain and "all other goods" should equal their price ratio (8a). Second, the storage-induced marginal utility loss of grain consumption plus the

marginal utility loss of income caused by storage costs in period 0 should equal the discounted marginal utility gain of grain consumption in period 1 brought by grain storage from period 0 (8b). Third, the utility gain of borrowing in period 0 should equal the discounted expected utility loss of repaying the loan in period 1 (8c).

Choice Functions. Provided that second order conditions hold, the optimal solution of the choice variables are defined as:

(9a) $$\Delta s_0^* = \Delta s_0(\bar{q}_0, P_{q0}, P_{f0}, \bar{q}_1, P_{q1}, P_{f1}, \alpha_1', r)$$

(9b) $$c_0^* = c_0(\bar{q}_0, P_{q0}, P_{f0}, \bar{q}_1, P_{q1}, P_{f1}, \alpha_1', r)$$

(9c) $$q_{f0}^* = q_{f0}(\bar{q}_0, P_{q0}, P_{f0}, \bar{q}_1, P_{q1}, P_{f1}, \alpha_1', r)$$

(9d) $$b_0^* = b_0(\bar{q}_0, P_{q0}, P_{f0}, \bar{q}_1, P_{q1}, P_{f1}, \alpha_1', r)$$

This theoretical derivation provides the basis for econometric analysis in the next chapter. However, since every parameter is included in more than one first order equation and in a nonlinear way, no definitive comparative statics results can be derived from this model[1]. In the next chapter, function (9a) through (9d) will be estimated linearly to examine the effects of variables identified in this theoretical framework on Chinese farmers' grain storage.

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[1] See Silberberg, P. 201.

Conditions for Positive Storage. It will prove useful to restate the first order condition for the change in storage (8b) in terms of marginal utility of income. In period 1, market sales are defined by another first order condition:

(10a) $$H_{q_{f1}} = -U_{c_1} + P_{f1}U_{y_1} = 0$$

Taking expectations for its relevance to period 0:

(10b) $$H_{q_{f1}} = E[-U_{c_1} + P_{f1}U_{y_1}] = 0$$

Substituting (8a) and (10b) into (8b), and obtain:

(11) $$H_{\Delta s_0} = -[P_{f0} + t_{\Delta s_0}]U_{y_0} + \varphi E[U_{y_1}P_{f1}] = 0$$

The sufficient condition for positive optimal additions to storage as in Saha and Stroud (1994) can be derived from equation (10) as follows:

(12) $$H_{\Delta s_0}|_{\Delta s_{0=0}} = \varphi E\left[U_{y1}P_{f1}\right]|_{\Delta s_{0=0}} - (P_{f0} + t_{\Delta s0})U_{y0}|_{\Delta s_{0=0}} > 0$$

where $|_{\Delta s_{0=0}}$ denotes "evaluated at $|_{\Delta s_{0=0}}$".

From (8c), $U_{y_0} = \varphi(1+r)EU_{y_1}$. Substituting into (12), yields:

(13) $$(1+r)^{-1}E(P_{f1}) - (P_{f0} + t_{\Delta s_0}) + \left.\frac{\mathrm{cov}(U_{y_1}, P_{f1})}{(1+r)EU_{y_1}}\right|_{\Delta S_0=0} > 0$$

This expression can be written as:

(14) $$\Delta P + \Omega > 0$$

where $\Delta P = (1+r)^{-1}E(P_{f1}) - (P_{f0} + t_{\Delta s_0})$ represents the real price change from

period 0 to period 1 and $\Omega = \left.\frac{\text{cov}(U_{y1}, P_{f1})}{(1+r)EU_{y1}}\right|_{\Delta s_0 = 0}$ can be interpreted as the income-security motive for grain storage. Saha and Stroud make two propositions for the inequality (14). First, under risk-neutrality, $\Omega = 0$. In this case, positive additions to on-farm storage happens only when the discounted expected real price increase exceeds storage costs, that is, $\Delta P > 0$. Second, under risk-aversion, $\Omega > 0$, if $(R - \eta) > 0$[2], where R is the index of relative risk-aversion and η is the income elasticity of grain food consumption. This suggests that positive additions to on-farm storage under risk-aversion can occur even if the discounted expected price increase is less than marginal storage costs. In the absence of an expected price increase, positive on-farm storage in developing countries can be explained by income- and food-security motives.

Average storage costs in rural China, including physical losses, quality degradation, cost of the storage facility and interest foregone, can be as high as 20 percent of the total value stored. This suggests that absent expected price increases the convenience yield (including food- and income-security) concerns must be particularly large to allow the positive grain storage occur. The desirable property of the model presented above is that its utility function contains grain consumption. This captures the property of own-produced grain as both a consumption good and an income good, thus making the derivation of general conditions of positive additions to grain storage

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[2] For the proof, see Newbery and Stiglitz. P. 117.

possible. This model also defines the relationship between individuals' attitudes toward risk (risk-neutral or risk-averse) and their storage activities.

CHAPTER 5

ECONOMETRIC ANALYSIS

Historically widespread famine, frequent changes in government grain policies, underdeveloped grain, and credit markets and farmers' attitudes toward risk have all played a part in influencing Chinese farmers' on-farm storage decisions. The theoretical framework in Chapter 4 identifies factors which may affect Chinese farmers' storage decisions. The empirical analysis in this chapter uses a newly acquired household survey data set from northeast China to examine the effects of these factors on grain storage. Northeast China is one of the largest wheat producing areas in China. Since wheat is the staple food in this area and China's wheat imports are of particular interest to wheat exporters, wheat storage is of particular concern of this thesis.

As defined through equations (9a), (9b) and (9c) in the theoretical framework, the change in wheat storage, wheat consumption, and wheat market sales will be estimated by explanatory variables which reflect information about household wheat output, the government procurement quota, wheat carry-over stocks from last year, wheat market prices, quota revenue and family characteristics.

Survey Data

The data set is an extensive cross-sectional household survey conducted under the direction of researchers at the University of California at Davis. The survey included 158

households located in 6 villages in two counties in Northeast China. Variables of primary interest include changes in wheat storage, wheat consumption, wheat market sales, wheat production, government wheat procurement quota, wheat prices, farm family characteristics, and borrowing (lending). This survey was conducted in March 1994, approximately 6 months after the wheat harvest. Descriptive statistics are given in Table 1.

Table 1: Descriptive Statistics of Data

Variable	N	Mean	St. Dev.	Minimum	Maximum
Change in Storage (Kgs.)	158	131.07	341.46	-602.00	1500.00
Consumption of Wheat (Kgs.)	158	734.63	363.54	0.00	1800.00
Market Sales of Wheat (Kgs.)	158	312.97	500.36	0.00	1750.00
Wheat Harvest (Kgs.)	158	1800.51	1112.06	350.00	7000.00
Wheat Quota (Kgs.)	158	353.46	494.22	16.00	2973.50
Percentage of Wheat Quota to Total Output	158	0.16	0.14	0.02	0.63
Carry-Over from Last Year (Kgs.)	158	392.72	378.56	0.00	2000.00
Quota Price	158	0.35	0.24	0.00	1.10
Market Price	158	0.67	0.09	0.49	0.94
Family	158	3.23	0.95	1.00	6.70
On-Farm Family Members, Working Age	158	2.34	0.99	0.00	5.10
On-Farm Family Members, Non-Working Age	158	0.69	0.53	0.00	2.00
Off-Farm Family Members, Working Age	158	0.20	0.56	0.00	4.40
Borrowing (Yuan)	52	3702.42	4456.53	0.00	20000.00
Lending (Yuan)	37	2758.65	2885.16	150.00	13000.00

The total wheat harvested by households is quite variable, ranging from 350 kilograms to 7000 kilograms, with an average of 1800 kilograms. Since the data was conducted almost one-half year after harvest, some storage held in storage may have already been consumed or sold. Change in storage ranges from -602 kilograms to 1500 kilograms, with an average of 131 kilograms, 7 percent of the average household's wheat harvest. Average household wheat consumption is 735 kilograms, 41 percent of the mean wheat harvest. The maximum household consumption is 1800 kilograms and the minimum is 0 kilograms. Household's market sales of wheat also varies considerably with a standard deviation of 500 kilograms, 160% of average wheat market sales. The maximum market sales of wheat is 1750 kilograms with a minimum of 0. The average of market sales is 313 kilograms, accounting for 17 percent of the average wheat harvest.

The maximum government wheat procurement quota is 2974 kilograms and the minimum is 16 kilograms. The average wheat quota is 494 kilograms. The proportion of quota to total output is highly variable, ranging from 2 percent to 63 percent, with an average of 16 percent. Demographic data include information about on-farm family members and their ages, and family members living off-farm. Among the 158 farm households in the sample, borrowing is reported by 52 households and lending by 37. The large number of missing observations on borrowing and lending precludes the inclusion of these variables in the econometric model presented below.

Some observations have missing data. Quota prices are not reported in three households while market prices are not reported in ninety-nine cases. Missing data on government procurement quota prices and market prices were replaced by village average prices in order to maintain a reasonable sample size. However, this replacement may have

reduce the variability in the two price variables, thus reducing the efficiency of estimations by increasing their standard errors.

Table 2 shows that wheat quota rices and revenues are highly variable within and between villages. The average quota price for the entire sample is 0.35 Yuan with a standard deviation of 0.24Yuan. Average household quota revenues are 294 Yuan with a standard deviation of 535 Yuan which is 182 percent of the mean. The highest quota price 0.52 Yuan/Kilogram, occurred in village 5, while the lowest average quota price, 0.02 Yuan/Kilogram, occurred in village 3. The highest average quota revenue, 1093 Yuan, occurred in village 6, while the lowest average quota revenue, 11 Yuan, occurred in village 3. Even within a given village, quota prices and revenues are diverse. The standard deviation of the quota price in village 4 is 49 percent of the mean. In village 1, it is 28 percent. The ratio of the standard deviation of quota revenue to its mean exceeds 40 percent in all 6 villages.

Table 2. Variances of Quota Prices and Quota Revenues

Village	Mean of Quota Price	Std. Dev.	Mean of Quota Revenue	Std. Dev.
Total	0.346	0.241	294.21	535.16
Village 1	0.495	0.141	56.19	29.48
Village 2	0.455	0.065	49.1	23.02
Village 3	0.022	0.103	11.37	55.45
Village 4	0.394	0.193	355.07	251.01
Village 5	0.522	0.062	1046.98	645.06
Village 6	0.503	0.074	1092.81	692.6

Explanatory Variables and their Expected Effects

Equations (9a), (9b) and (9c) in the theoretical framework defined the three dependent variables—the change in wheat storage, wheat consumption and wheat market sales. Estimations of these variables will allow a better understanding of Chinese farmers' decisions on wheat storage, consumption and marketing. It is of particular interest of wheat exporters to China and domestic policy makers. The explanatory variables of interest are related to household wheat output, government procurement quotas, wheat carry-over stocks, wheat prices and family characteristics. The explanatory variables and their expected effects are described as follows.

Available Working Wheat

This variable contains information about the actual amount of wheat available to farmers for storage, marketing and consumption uses. It is constructed by deducting the government wheat quota, seed, feed, and the amount of household wheat exchange from the total household output. Given that the wheat and credit markets are still underdeveloped in China, the change in storage is hypothesized to be directly related to the amounts of available working wheat.

Under the assumption that wheat consumption is a normal good, wheat consumption is expected to be positively related to the available working wheat. Market sales are also expected to be positively related to available working wheat.

The Government Wheat Quota

Chinese farmers must fulfill government wheat quotas or they will face severe cash penalties. Farmers therefore have an incentive to store wheat to insure against potential poor harvests. The variable available working wheat already accounts for the negative effects of government quota requirements on storage, namely, the higher the quota, the less available working wheat is left to farmers. Therefore, the government wheat quota variable measures only the additional food- and income-security effects of the quota on wheat stocks. Since the possibility of not being able to fulfill the quota is directly related to amounts of the quota and failure to fill the quota will cause severe cash penalties, farmers are expected to store more wheat when the government quota increases. Therefore, the change of storage is hypothesized to be positively related to this government wheat quota, consumption, and market sales are expected to be negatively related to this government wheat quota.

Carry-Over of Wheat Stocks from Last Year

This variable measures the amount of wheat carried over from last year just prior to harvest. The carry-over from last year reduces storage requirements in the current period, therefore, the change in storage is expected to be inversely related to the carry-over.

Under the normal good assumption, wheat consumption is expected to be positive related to this variable. Wheat carry-over stocks increase the wheat available for market sales, therefore, market sales are expected to be directly related to this variable.

Quota Revenue

Quota revenue is a close but not perfect substitute for revenue from all sources. The total household income is not included in the survey. In addition, since market sales of wheat is a choice variable, revenue from wheat market sales should not be included in exogenous variables. In this case, since quota revenue is predetermined and an important income source for most Chinese farm households, it is expected to serve as the substitute for income. Recall however from Chapter 3 that quota revenue is not paid immediately and is not guaranteed.

Quota revenue was constructed by multiplying the amount of government procurement quota with its price. It reflects the influence of the income level on farmers' willingness to take risks. As previously discussed, the total opportunity cost of storage in China, including physical storage costs, interest forgone and loss of quality and quantity, could be as high as twenty percent of the value of the stored wheat (Watson and Song, 1998). In addition to storage costs, risk-aversion may be an important factor in farmers' decisions on storage. If absolute risk-aversion is greater among low-income farmers (Newbery and Stiglitz, 1981), the change of storage is hypothesized to be negatively related to quota revenue.

Consumption is expected to be positively related to quota revenue if wheat for food consumption is a normal good. If increases in quota revenue might reduce additions to storage due to changes in absolute risk-aversions, more wheat would be available for market sales. Therefore, market sales are expected to be positively related to quota revenue.

Relative Market Premium

If Chinese farmers store grain primarily because of food- and income-security concerns, as proposed by Ke (1996), then storage should be relatively price-inelastic. The individual household in an sample of 158 households is very small compared with the total market, therefore, individual households are assumed to be price takers. The relative market premium is measured by the percentage difference between the market price and the quota price for wheat. The change in storage is expected to be inversely related to this variable.

The effect of relative market premium on consumption is uncertain because of the offsetting income and substitution effects. Market sales are expected to be directly related to relative market premium.

The Number of On-Farm Family Members (Man-Power Equivalents).[3]

Information about on-farm family members is of interest because it is closely related to consumption requirements and farm inputs (labor availability). On-farm family members are divided into two categories. The first category includes on-farm family members of non-working age (under 13 or above 60). The second category includes on-farm family members of working age (between 13 and 60). On-farm family members of working age can affect dependent variables through both consumption requirements and their potential as farm labor inputs or for off-farm labor. On-farm family members of

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3. Man-power equivalents are constructed based on the estimated earning power of different ages and genders (Saha and Stroud, 1994). Men aging between 13 and 60 are one man-power unit, with females in the same age range 0.7 man-power units. People under 13 or above 60 years old are 0.5 man-power unit.

non-working age are assumed not to have these labor functions. The expected effects of these two variables are discussed as follows:

On-Farm Family Members of Non-Working Age. The number of on-farm family members of non-working age has two offsetting effects on household wheat storage. First, it may affect household wheat storage by increasing annual consumption requirements to be met by storage. Second, since storage is recorded approximately 6 months after the actual harvest, a large amount of the stored crop will have already been consumed. These two effects influence storage in opposite ways. The expected effect of this variable on the change in storage is therefore uncertain, depending on their weights.

Consumption is expected to be directly related to the number of on-farm family members of non-working age because of consumption requirements of these on-farm members. For the same reason, on-farm family members of non-working age reduces the amount of wheat available for market sales. Therefore, market sales are expected to be inversely related to this variable.

On-Farm Family Members of Working Age. Besides the two offsetting effects discussed for on-farm non-working family members, this variable also includes the risk-reducing potential of off-farm work, potentially reducing storage. The ability of family members to work off-farm increases the food- and income-security of the farm household. The effect of this variable on the change in storage is uncertain, but is hypothesized to be significantly smaller than that of on-farm non-working family members.

Similarly, consumption is hypothesized to be positively related to on-farm members of working age and market sales are expected to be inversely related to on-farm members of working age.

The Number of Family Members (Man-Power Equivalents) Working and Living Off-Farm

The number of family members working (aging between 13 and 60) off-farm is hypothesized to reduce household wheat storage. The potential for off-farm working members to remit income back to the farm family is a risk-reducing factor since off-farm income is usually more stable than that from agricultural production. To the extent that wheat storage is driven by income-security motives, more family members working off-farm will lead to less wheat storage.

Since an off-farm family member is defined to be living off-farm for six or more months, the effect of the variable on consumption is hypothesized to be small and positive, if significant. Market sales are expected to be directly related to this variable since it may reduce the amount of wheat needed for storage, thus providing more wheat for marketing.

Estimation Model and Results

Dependent variables to be estimated include the change in wheat storage, wheat consumption and market sales of wheat. They are presented in linear reduced forms as follows:

$$(15a)\quad \Delta s_0 = \alpha_s + \beta_{s1} w_0 + \beta_{s2} \bar{q}_0 + \beta_{s3} s_0 + \beta_{s4} mp_{f0} + \beta_{s5} P_{q0} \cdot \bar{q}_0 + \beta_{s6}' f + \beta_{s7}' f + \varepsilon_{\Delta s_0}$$

$$(15b)\quad c_0 = \alpha_c + \beta_{c1} w_0 + \beta_{c2} \bar{q}_0 + \beta_{c3} s_0 + \beta_{c4} mp_{f0} + \beta_{c5} P_{q0} \cdot \bar{q}_0 + \beta_{c6}' f + \beta_{c7}' D_v + \varepsilon_{c_0}$$

$$(15c)\quad m_0 = \alpha_m + \beta_{m1} w_0 + \beta_{m2} \bar{q}_0 + \beta_{m3} s_0 + \beta_{m4} mp_{f0} + \beta_{m5} P_{q0} \cdot \bar{q}_0 + \beta_{m6}' f + \beta_{m7}' D_v + \varepsilon_{m_0}$$

Initial OLS results suggested strong heteroscedasticity related to household planting area and self-reported percentage of good land. Since this data set contains only one year of cross-sectional data, actual total wheat output of the household contains too many random errors to serve as a normalizing factor. Household expected output[4] computed on the basis of average output within the village, was constructed as an alternative normalizing factor. The three dependent variables in equation (15a)-(15c) and all independent variables except the market price premium are divided by this normalizing variable.

Plots of errors against farm size and percentage of good-quality land illustrate much less apparent heteroscedasticity after this normalization. The regression results were robust to removing apparent outliers. The normal distribution of residuals was not rejected the by Kolmogorov test, with a value of 0.97 for change in storage. Kolmogorov normality tests for residuals for consumption and market sales are 0.97 and 0.96, respectively. Normal distribution of residuals was not rejected in any estimation.

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4. Village average yield for each self-reported quality (good or bad) of land was first calculated, then each individual household's expected output was computed by multiplying their planted acreage of each quality of land by the village average yield of that land quality.

Seemingly Unrelated Equation System (SUR) Estimation and Results

Because of the close relationship between the change in storage, consumption and market sales, the OLS procedure is likely to have a potential contemporaneous error problem. Cross-equation errors can be correlated, yielding a cross-equation covariance matrix that is non-diagonal. This problem will result in an efficiency loss in estimation. A restricted seemingly unrelated equation (SUR) approach is used to correct this problem (Greene, 1993). Instead of estimating the three choice variables—change in storage, consumption, and market sales of wheat—separately using OLS procedure, the SUR approach estimates the three variables simultaneously through the maximum likelihood estimation. This feature enables the SUR model to make use of the full information provided by the system of equations.

Recall that the two-period household utility function includes choice variables for change in storage consumption, market sales of grain, and borrowing and lending. Due to a large number of missing observations, borrowing and lending can not be efficiently estimated. The SUR procedure is used to estimate the change in wheat storage (Δs_0), wheat consumption (c_0) and market sales of wheat (m_0). The restricted seemingly unrelated equation system for the linear reduced form estimation equations is:

(16a) $$\Delta s_0 = \alpha_s + \beta_{s1} w_0 + \beta_{s2} \bar{q}_0 + \beta_{s3} s_0 + \beta_{s4} mp_{f0} + \beta_{s5} P_{q0} \cdot \bar{q}_0 + \beta_{s6}' f + \beta_{s7}' D_v + \varepsilon_{\Delta s_0}$$

(16b) $$c_0 = \alpha_c + \beta_{c1} w_0 + \beta_{c2} \bar{q}_0 + \beta_{c3} s_0 + \beta_{c4} mp_{f0} + \beta_{c5} P_{q0} \cdot \bar{q}_0 + \beta_{c6}' f + \beta_{c7}' D_v + \varepsilon_{c_0}$$

(16c) $$m_0 = \alpha_m + \beta_{m1} w_0 + \beta_{m2} \bar{q}_0 + \beta_{m3} s_0 + \beta_{m4} mp_{f0} + \beta_{m5} P_{q0} \cdot \bar{q}_0 + \beta_{m6}' f + \beta_{m7}' D_v + \varepsilon_{m_0}$$

The dependent variable Δs_0 in equation (15a) denotes the change in wheat storage. The variable w_0 represents the available working wheat. The government

procurement wheat quota is denoted by $\bar{q}_0$. Carry-over stocks of wheat from last year are denoted by s_0 The percentage premium of the market price is denoted by $P_{q0} \cdot \bar{q}_0$. Family information is denoted by the vector f and includes on-farm family labor, on-farm non-working family members, and off-farm family labor. D_v denotes a vector of five village dummy variables. The other two dependent variables, wheat consumption and market sales of wheat, are denoted by c_0 and m_0 in equation (15b) and (15c), respectively and are estimated using the same exogenous variables used for the change in wheat storage.

The amount of available working wheat (production less the fixed government quota, seed, feed, and exchange) is fixed and allocated to change in storage, consumption, and market sales. Therefore, coefficients of parameters except available working wheat in the three equations (16a), (16b), and (16c) are restricted to sum to 0. The coefficients of available working wheat in three estimation equations should sum to 1. This SUR model is a full information estimator, asymptotically more efficient than separate OLS estimators for the change in storage, consumption and market sales. An F test failed to reject the group insignificance of village dummy variables, with a value of 0.47, less than the critical value of 4.40 at 5 percent level (degree of freedom is 5 for denominator and 149 from numerator). Therefore, village dummy variables were excluded from the regression. Results of the seemingly unrelated system estimation for the change in storage, consumption and market sales are presented in Table 3. Elasticity estimates from the SUR estimation at the variable means are listed in Table 4.

Table 3: Seemingly Unrelated Estimation Results

	Change of Storage†	Consumption†	Market Sales †
Constant	0.069 (1.77)*	-0.041 (-1.040)	-0.038 (-0.987)
Available Working Wheat†	0.304 (4.237)***	0.489 (6.750)***	0.206 (2.904)***
The Government Wheat Quota †	0.368 (0.671)	-0.477 (-0.866)	0.109 (0.201)
Carry-Over of Wheat Stocks from Last Year†	-0.165 (-3.450)***	0.001 (0.015)	0.164 (3.465)***
Relative Market Premium	-0.141 (-3.206)***	0.055 (1.234)	0.086 (1.981)**
Quota Revenue†	-1.408 (-1.328)	1.081 (1.009)	0.327 (0.312)
Number of On-Farm, Working Age†‡	-10.116 (-0.684)	57.798 (3.864)***	-47.682 (-3.263)***
Number of On-Farm, Non-Working Age†‡	-65.531 (-2.369)**	122.14 (4.369)***	-56.606 (-2.070)**
Number of Off-Farm, Working Age†‡	-125.22 (-2.878)***	80.538 (1.833)*	44.684 (1.039)
Adjusted R^2	0.36	0.38	0.29
System R-Square: 0.9193			
Likelihood Ratio Test of Diagonal Covariance Matrix: 255.91 with 3 D.F.			

T-statistics are in parenthesis

* = significant at 0.10; ** = significant at 0.05; *** = significant at 0.01.

† = normalized by the expected output.

‡ = man-power equivalents.

N = 158

Table 4: Elasticity Calculations for SUR Model

	Change of	Consumption	Market Sales †
Available Working Wheat†	2.90***	0.72***	1.09***
The Government Wheat Quota†	0.78	-0.16	0.13
Carry-Over of Wheat Stocks from Last Year†	-0.64***	0.001	0.35***
Relative Market Premium	-1.94***	0.12	0.66**
Quota Revenue†	-1.16	0.14	0.15
Number of On-Farm, Working Age†‡	-0.23	0.20***	-0.60***
Number of On-Farm, Non-Working Age†‡	-0.46**	0.13***	-0.22**
Number of Off-Farm, Working Age†‡	-0.20***	0.02*	0.04

* = significant at 0.10; ** = significant at 0.05; *** = significant at 0.01.
† = normalized by the expected output.
‡ = man-power equivalents

The amount of available working wheat significantly increases storage, consumption and market sales. Change in storage and market sales are elastic with respect to this variable (2.89 and 1.09, respectively) while consumption is inelastic (0.72). The positive relationship between change in storage and available working wheat supports the hypothesis that credit or grain markets or both in rural China are still not mature. Storage provides a saving mechanism for Chinese farmers. Farmers store more wheat for food- and income-security reasons when there is more wheat available. The fact that more available working wheat leads to more consumption suggests that farmers' wheat consumption has not reached the satiation level.

Increased wheat carry-over stocks significantly reduce change in storage and increase market sales, supporting the hypothesis that carry-over from last period reduces the addition to storage in the current period, providing more wheat for market sales. However, the effects of carry-over are small in percentage terms and not elastic in either estimation (-0.64 for the change in storage and 0.35 for market sales). Carry-over stocks have no significant effects on consumption. Given the high degradation of grain storage in China, farmers appear to be keeping a relatively constant level of carry-over in order to mitigate storage costs.

The ratio of the change in storage to expected output is negatively related to the relative market premium and is price elastic, the price elasticity is -1.84. Storage by these Chinese farmers appears to be somewhat price-responsive. This result contrasts with Ke's (1996) suggestion that Chinese farmers' grain storage is generally price inelastic. Additional studies are needed in order to resolve this issue.

Wheat market sales are positively related to relative market premium as hypothesized, with a elasticity of 0.66. Farmers' wheat consumption is not significantly affected by the relative market premium, suggesting that the offsetting income and substitution effects are of similar magnitudes. The estimation results also suggest that the relative market premium affects change in wheat storage through both market sales and to some degree consumption.

The government wheat quota and quota revenue variable have no significant effects on any of the three models beyond the quota effect on available working wheat. Recall from Table 1 that the average percentage of quota to total output is only 16 percent, and thus may not have large effects on farmers' decisions on wheat allocations

beyond the effect on available working wheat. However, the apparent collinearity between the government wheat quota and quota revenue variables may contribute to their insignificance and will be explored in a restricted model.

The composition of the farm household proves an important factor in determining farmers' wheat allocation among change in storage, consumption and market sales. The number of on-farm family members (man-power equivalents) of non-working age significantly reduces additions to storage and market sales while increasing consumption. Since the survey was conducted about six months after the harvest, a large amount of wheat storage must have already been consumed. The elasticities for the change in storage, consumption and market sales are inelastic.

The number of on-farm family members (man-power equivalents) of working age significantly increases consumption and reduces market sales. However, it is not elastic for either variable (0.20 for consumption and -0.59 for market sales). This variable has no significant effects on the change in storage, different from the estimated result of the number of non-working age on-farm family members. Most importantly, the magnitude of coefficient for working age on-farm family members (man-power equivalents) is significantly smaller in absolute value than that for the non-working on-farm family members (man-power equivalents), proved by a T test with a value of 1.727. This effect on storage is consistent with the estimation results for consumption which suggest that working age on-farm family members (man-power equivalents) consume less than non-working age on-farm family members (man-power equivalents). These results might imply that diets for working family members may be different from those for non-working family members. Working family members could consume less wheat and more

other dietary components such as meat. Another possible explanation is that since man-power equivalents are calculated based on earning power rather than dietary requirements, non-working members' wheat consumption may be somewhat over-discounted by these equivalents.

The number of off-farm family members of working age significantly reduces the household wheat storage, although the effect is not elastic (-0.20). This result provides support for the income-security hypothesis, that is, that family members working off-farm add income-security to the farm household income through their potential remittance. This variable also significantly (at a 10 percent level) increases consumption, suggesting that some off-farm working family members may still consume grain from the farm. The elasticity of this is extremely small, however.

Restricted Model

Multicollinearity problems appear to exist between the government quota and the quota revenue variables. To better understand the effect of quota, two restricted models are considered. The first model omits the government quota variable (retaining the quota revenue). The second model omits the quota revenue variable (retaining the quota variable). The System R-Squared is 0.9188 when the government quota is omitted and 0.9183 when the quota revenue is omitted, showing more predictive power for the model omitting the government quota variable rather than the quota revenue variable. Estimation results and calculated elasticities of the restricted model omitting the government quota variable are listed in Table 5 and Table 6.

Table 5: Seemingly Unrelated Estimation Results of the Restricted Model

	Change of Storage†	**Consumption†**	**Market Sales †**
Constant	0.069 (1.66)*	-0.032 (-0.851)	-0.040 (-1.078)
Available Working Wheat†	0.308 (4.329)***	0.483 (6.711)***	0.207 (2.946)***
Carry-Over of Wheat Stocks from Last Year†	-0.167 (-3.495)***	0.004 (0.072)	0.164 (3.465)***
Relative Market Premium	-0.116 (-5.055)***	0.022 (0.96)	0.094 (4.135)**
Quota Revenue†	-0.715 (-3.002)***	0.018 (0.759)	0.532 (2.263)**
Number of On-Farm, Working Age†‡	-9.539 (-0.647)	57.049 (3.830)***	-47.511 (-3.265)***
Number of On-Farm, Non-Working Age†‡	-66.303 (-2.401)**	123.14 (4.411)***	-56.835 (-2.084)**
Number of Off-Farm, Working Age†‡	-120.15 (-2.806)***	73.958 (1.709)*	46.189 (1.092)
Adjusted R^2	0.35	0.38	0.29
System R-Squared: 0.9188			
Likelihood Ratio Test of Diagonal Covariance Matrix: 256.40 with 3 D.F.			

T-statistics are in parenthesis

* = significant at 0.10; ** = significant at 0.05; *** = significant at 0.01.

† = normalized by the expected output.

‡ = man-power equivalents.

N = 158

Table 6: Elasticity Calculations for Restricted SUR Model

	Change of Storage†	Consumption†	Market Sales †
Available Working Wheat†	2.94***	0.72***	1.09***
Carry-Over of Wheat Stocks from Last Year†	-0.64***	0.002	0.35***
Relative Market Premium	-1.60***	0.05	0.71***
Quota Revenue†	-0.59***	0.02	0.24**
Number of On-Farm, Working Age†‡	-0.22	0.20***	-0.59***
Number of On-Farm, Non-Working Age†‡	-0.46**	0.13***	-0.22**
Number of Off-Farm, Working Age†‡	-0.19***	0.02*	0.04

* = significant at 0.10; ** = significant at 0.05; *** = significant at 0.01.
† = normalized by the expected output.
‡ = man-power equivalents

After omitting the government quota, the quota revenue variable becomes significant. This variable significantly reduces additions to storage, consistent with decreasing risk-aversion, namely, farmers tend to be less risk-averse and thus store less when their incomes increase. Increase in quota revenue also significantly increases market sales of wheat. Since farmers store less along with increasing incomes, more wheat is available for market sales.

In total, the SUR results provide useful information about wheat storage, consumption and marketing decisions for farmers in Northeastern China. Available working wheat significantly increases the change in storage, suggesting immature credit and grain markets in China and that wheat storage provides a saving function for Chinese

farmers. Carry-over, relative market premium, on-farm non-working family members and off-farm working family members significantly reduces additions to storage.

Farmers' wheat consumption is not significantly affected by the relative market premium. It suggests that the offsetting income and substitution effects have similar magnitudes. The result that off-farm working family members still affect consumption suggests that a large number of these rural labors may still consume wheat from the farm.

Market sales of wheat are significantly increased by available working wheat, the carry-over from last year and the relative market premium. Among these factors, the available working wheat is elastic while the relative market premium and the carry-over from last year are not. The combined result suggests the change in market supply by these farmers is more responsive to the change in output than to change in price factors.
In the restricted model, quota revenue significantly decreases additions to storage and increases market sales, indicating that food- and income-security concerns are important factors in farmers' decisions on wheat allocations.

CHAPTER 6

SUMMARIES AND CONCLUSIONS

China's grain imports have gradually become an important factor influencing the international grain market. The quantity China imports, however, is highly variable. A key factor affecting China's grain imports is China's substantial amount of on-farm grain storage.

There are three types of grain stocks in China—state strategic grain reserves, Local government working stocks, and on-farm grain storage by farmers. The first two are public buffer stocks which serve primarily to stabilize domestic grain prices and their quantities remain relatively stable. The on-farm grain storage held by farmers, comprising of about half of China's total grain storage, is both the most variable and the least understood.

Ke (1996) has suggested that major reasons for farmers' on-farm storage include food-security concerns, poor transportation conditions, different income levels, and different harvest schedules. Johnson and Song (1998) indicated that on-farm grain storage primarily functions as insurance against poor harvests, hyperinflation, and income shocks. So far, little conclusive research on this issue has been carried out due to the difficulty of obtaining pertinent data and lack of transparency of Chinese agricultural policy. Using data from a new household survey in northeastern China, this thesis suggests that government grain policies, unreliable grain markets, and food- and income-

security concerns are some of the most important factors influencing Chinese farmers' on-farm grain storage.

Due to a history of widespread famines, wide weather variation, still developing infrastructure and imperfect grain and credit markets, Chinese farmers have a long tradition of storing large quantities of grain. After the foundation of People's Republic of China in 1949, government policies changed frequently and dramatically, ranging from complete control on production and distribution to allowing farmers considerable freedom.

Two core components of China's grain policy continue to affect farmers' on-farm grain storage. The first is the fixed government procurement quota. Farmers are obliged to deliver a certain amount of grain upon harvest to the government at a price lower than market price. Failure to fulfill this quota can result in severe cash penalties. The second is that farmers are not eligible to purchase grain from government food agencies which control 70 to 80 percent of the marketed surplus of grain. Farmers are required to consume their self-produced grain or purchase it from free grain markets, frequently at prohibitive prices. Due to the government quota, farmers tend to store additional grain in order to avoid potential failure to submit the government quota. Farmers' inability to purchase grain from government food agencies is expected to lead them to store a considerable amount of grain for their food consumption. The great variability of both quota and quota prices in the data set used for econometric analysis allows this thesis to provide some useful information about effects of the quota on Chinese farmer's grain storage decisions.

Besides self-production, another source for farmers' food supply is the free grain market. However, Chen (1994) has suggested that the free grain market in China was segmented and underdeveloped at the end of 1993. The government also often intervenes these markets. For instance, the free grain market is usually closed during the government procurement period until quota in the local area has been fulfilled. As a whole, bureaucratic obstacles, regional blockades, high transportation cost, plus lack of inexpensive information prevent the free grain market from being a stable source of food supply for Chinese farmers.

This thesis used a two-period household utility maximization model to analyze Chinese farmers' grain storage, grain consumption, market sales of grain, and borrowing and lending. The major contribution of this model is the addition of the government procurement quota. This model identifies key factors influencing Chinese farmers' decisions on grain allocations. Through this model, similar conditions for positive grain storage with consideration of farmers' risk attitudes (food and income security concerns) were derived as those by Saha and Stroud (1994). Unfortunately, comparative statistics results are limited because every parameter enters all the first order condition. However, linear reduced form equations provide insights into farmers' wheat storage, consumption and market sales.

A cross-sectional household survey data of the on-farm grain storage in Northeastern China was collected under the instruction of researchers at University of California at Davis. Northeastern China is one of the major grain producing areas in China. This data set was very extensive, including information about farmers' grain storage, consumption, market sales, and government procurement quota. Since wheat is

the staple crop in the local area and China's wheat imports are of particular interest to grain exporters to China, the empirical analysis focuses on wheat storage.

A restricted seemingly unrelated equation system was used to estimate change in wheat storage, wheat consumption, and market sales of wheat. The estimation results suggested that the market price of wheat significantly affected farmers' storage, and it is also somewhat price-elastic (with an elasticity of -1.94). This result contrasts the suggestion by Ke (1996) that Chinese farmers' on-farm grain storage is generally price-inelastic.

When both included in the model, the fixed government quota and quota revenue did not significantly affect their wheat storage, However, this may be due to the multicollinearity between these two related variables. In a restricted SUR model where the government quota is omitted, the quota revenue significantly reduces additions to storage and increases market sales, supporting the hypothesis that farmers' risk-aversions tend to be reduced associated with higher income levels. This model is superior in fit to another restricted model where the quota variable is retained and quota revenue variable is omitted.

Another important finding of this thesis is that the number of family members living or working off-farm significantly reduce household wheat storage. This finding again supports the food-security/income-security hypothesis for storage because potential risk-mitigating remittances from off-farm family labors reduce the storage requirements.

In summary, for historical policy reasons, farmers are excluded from government grain distribution channels. The research of this thesis suggests that this policy plus the underdeveloped free grain markets encourages self-provision of grain for the farmers.

Farmers store a considerable amount of grain for their food consumption requirements. In addition, due to highly variable grain production, still developing infrastructure, and imperfect grain and credit markets in rural China, Chinese farmers are also storing for food-security concerns.

Suggestions for Further Research

Regrettably, this data is only an one year cross-section data. The lack of time series data prevents the consideration of some important factors including yield variance, interest rates, farmers' expected prices, and institutional changes. The addition of these important factors into the econometric estimation model would very likely provide more insights about how food-security concerns affect farmers' on-farm grain storage in developing countries. Information about household borrowing and lending is also limited in this data (see Table 2). If this information had been obtained, some analysis about the situation of rural China's credit market could have been conducted, and the seemingly unrelated system would have included all choice variables in the utility maximization problem defined in the theoretical work. In future surveys, information about quantity and quality loss of storage, transaction costs of purchasing and selling grain in the market is also desirable.

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