University of Alberta

China's Grain Consumption Demand and Its Implications for Canada-China Grain Trade

by

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CHAPTER 1 INTRODUCTION AND STATEMENT OF RESEARCH PROBLEM

This thesis study is concerned with projections of China's future grain demand and the implications of these for the world grain market. Most projections of China's future grain import demand have focused on economic factors that relate to the growth in demand for grain, either directly consumed or as derived from the demand for meat and beverages. Many studies have placed little emphasis on the technical issue of the grain-meat conversion ratios that are inherent in current meat production technologies and the likelihood that these technologies may persist for a considerable period of time. The lack of information and emphasis on current livestock production technologies has made it difficult or impossible to accurately project future demand for feed grain consumption. Inaccurate projections of the demand for feed grain consumption will lead to inaccurate projections of grain import demand.

Analysis of the technologies for different modes of livestock production and the assessment and adoption of an appropriate grain meat conversion ratio to arrive at projections of future feed grain demand can be expected to lead to improved forecasts of grain import demand. This will in turn help analysts and policy makers to better understand the world grain market and correctly identify the prospects for future growth in demand.

Partial adjustment models and time-varying parameter models of demand are developed and applied to estimate future demand for food grain, feed grain, usage of grain in beverages (thereafter referred to as spirits) and other grain usage for the period from 1952 to 1999. The resulting estimates of elasticities of demand are employed in simulations of future grain demand that are based on the analysis of current modes of livestock production technologies. Projections of future feed and grain import demand at five-yearly intervals for the period 2005 to 2020 are derived from the simulation analysis.

1.1 Background to the Research Problem

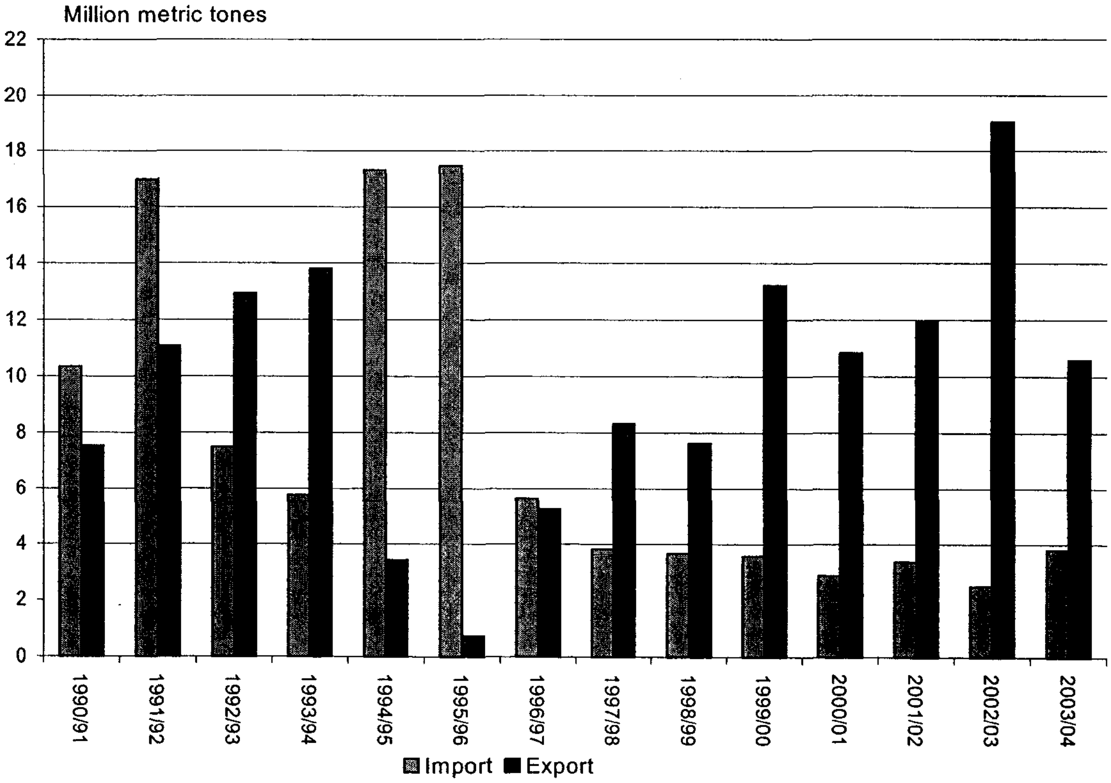
Since the adoption of the "open door" policy during the 1980s, China has experienced rapid growth in Gross National Product (GNP) and per capita income. Per capita GNP increased at a pace of more than 14% annually in the period 1990-2001 (SSB, various issues). Foreign currency reserves increased to the value of $ 46.6 billion U.S. in 2001 (SSB, various issues). Such rapid economic growth is leading to fundamental changes in the structure of human diets, particularly with urbanization, as people shift from rural to urban areas. The contribution of livestock products to human diets has increased and this trend is expected to continue and lead to an increase in the demand for feed grain. The changes in the demand for food, coupled with projections that China's population will increase from approximately 1.3 billion people in 2000 to 1.5 billion in 2025, have raised considerable speculation about the sufficiency of domestic feedstuffs for livestock, in addition to the nature of human demand for grains, vegetables and other agricultural commodities. An overview of grain production, consumption and trade for China is provided in Appendix 5.

Projections from several studies have been made within and outside China suggesting the likelihood that China would be a major importer in the world grain market by the end of the 20th century (Huang and Rozelle, 2003; Huang, Rozelle and Rosegrant, 1997; Fan and Sombilla, 1997; FAO, 1995; USDA/ERS, 1997). Concerns have even been expressed that China could "starve the world" by the year 2030 (Brown, 1995). Numbers of economists' projections were made, during the 1990s, projecting grain importation in the range of 11-26 million metric tones by the year 2000 (Table 2-6). This has not materialized in reality. Contrary to many projections that China was likely to be a net feed grain importer by year 2000, this country continues to be a major exporter of maize and oilseed meals (USDA/ERS, 2000). Since 2000, China has been exporting feed grain in the order of 10 million metric tons per annum. Available data show that China maintained approximately balanced trade in grain in the year 2003/04. (USDA/ERS, various issues). In 2002, the first year for China as a WTO member, this nation was a larger net exporter of grain (grain exports increased by 13.5% while imports rose by 3.5% during calendar year 2002 with a net grain trade surplus of more than 1 billion US dollars) (USDA/ERS, 2003). It appears that over-estimation of feed grain demand is an important reason for previous exaggerated predictions of Chinese grain imports.

China is the world's largest producer and consumer of wheat, rice, cotton, and oilseeds. In 2002, China produced 16% of the world's wheat and 32% of the world's rice in total. At the same time, China also consumed 18%

of the world's wheat and 33% of the rice (USDA/ERS, various issues). Grain production levels in China totaled 349 million metric tones in 2002, while grain consumption stood at 383 million metric tons. If production were to have fallen by 10% percent in the subsequent year, China would have suddenly found itself short of 35 million metric tons of grain and be the leading global importer (Figure 1-1). Given China's dominant position in both grain production and consumption, accurate projections of trade are of importance; policy based on inaccurate predictions could be disruptive to agricultural markets.

Figure 1-1 China Total Grain Import and Export Volumes, 1990/91-2003/04
Unit: Million Metric Tons



Projecting grain trade accurately is especially important to Canada since Canada is China's largest trading partner in wheat. In 1999/2000, China imported 1 million metric tones of wheat from the international market, of which 66 percent was from Canada (Statistics Canada, various issues). During 1991/92 to 2000/01, the 10-year average exportation of wheat from Canada to China constituted 17% of Canada's total wheat exports. Similar figures for barley show Canada exporting 18% of that crop to China, while 15% of canola exports from Canada are to China. Table 1-1 shows China's wheat importation by product origin. Canada is the largest supplier, accounting for 51% of total China's wheat imports in 2003.

Table 1-1 China's Wheat Imports By Origin, Mid-Year 2002/2003
Unit: 1,000 Metric Tons

Country	Jul-Sep	Oct-Dec	Jan-Mar	Total	Share (%)
Canada	73	12	64	149	50.9
United States	14	38	21	73	24.9
Australia	35	4	3	42	14.3
Japan	3	4	3	10	3.4
South Korea	2	3	3	9	3.1
Nepal	1	1	0	3	1
Italy	1	1	1	2	<1
Thailand	0	1	1	2	<1
United Kingdom	0	0	0	1	<1
All Others	3	0	1	2	<1
Grand Total	132	64	97	293	100

Source: USDA/ERS (2003)

In sum, for China, as Simpson et al. (1994, p xv) states: "Food security is a very sensitive issue within China and breaches in it could have severe repercussions on world political stability."

1.2 The Problem and Research Objectives

China, then, plays a major role in the international grain market. Canada has recently been China's biggest grain trading partner in terms of both volume and importance. Yet, the demand for grain in China is very unstable and hard to predict. What is especially unclear is China's feed grain demand. Feed grain demand was thought by some commentators to be the most rapidly expanding sector of demand (Tuan, 1987; Rosegrant et al, 1995; Hayes, 1999). However, there are no explicit official Chinese data about feed grain usage before the 1990s. The situations of feed grain usage and the possible demand for feed grain are obscure.

Previous studies of grain import demand have provided very limited information on feed grain import demand. The demand for feed grain is typically estimated indirectly by first projecting meat demand and multiplying this by typical grain-meat conversion ratios for pigs and beef cattle. The derived quantities are compared with the production of grain (generally maize, as an energy source and soybean, as a protein source) to determine whether imports will be required. Examples of the use of this procedure are Carter and Zhong (1991), and Huang et al. (1999).

There are several limitations associated with these kinds of studies. First, the grain-meat conversion ratios that have often been used are problematic, since most Chinese livestock producers frequently feed by-products, non-conventional feed resources (NCFR[1]) and other edible waste products, as well as mixed feeds. In these circumstances the conventional feed conversion ratio has less meaning and becomes an unreliable means to calculate feed grain demand. Second, current grain-meat conversion ratios are changing as production practices change and technology and management improves. Third, national meat production data for China lack accuracy, in part because of the prevalent style of backyard animal production in China. Inaccuracies in meat consumption data will translate into inaccurate predictions of feed grain demand. Another major drawback has been failure to consider developments in China's livestock and agriculture and the tendency to equate China's situation with Taiwan, Japan or the Republic of Korea, which are all mountainous countries with very little arable land. The situation in China is very different from these nations (Simpson et al., 1994). The rapid development of China also makes the adoption of appropriate grain-meat conversion ratios more complicated.[2]

A further reason for interest in China's potential import demand for grains is the lack of quantitative analysis and qualitative policy assessments of potential impacts on Canada from potential changes in China's feed grain demand and the changing nature of food consumption patterns.

In the light of the above reasons, the following research objectives are set up for this study:

(1) To compare previous projection models of Chinese grain production, consumption and trade, and, in particular, to critically review models which predict feed grain demand.

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[1] The term NCFR has been defined by Devendra (1992) as "all those feeds that have not been traditionally used in animal feeding or are not normally used in commercially produced rations for livestock."

[2] Due to the development of modern freeways and improved transportation networks in China, pig production in coastal areas has faced increasing competition from inland small producers who still rely on more traditional modes of production. As a result, the commercial production sectors in coastal areas have not expanded as rapidly as predicted. Thus the national aggregate grain-meat conversion ratios in China have not increased as quickly as expected and feed grain use has not risen as rapidly as many researchers once anticipated. See Chapter 5 for more discussion.

(2) To assess the feedstuff usage in different production modes in China. Processed feed, by-products and non-conventional feed resources (NCFR) are considered in detail. From this, an adjusted grain-meat conversion ratio will be derived.

(3) To analyze the determinants of grain consumption demand from 1952 to 1999 using econometric models and three related sub-models, for direct grain consumption (ie food grain demand); indirect grain consumption as feed grains; and the indirect demand for grain for beverage in China. A related objective is to compare the forecast accuracy of the partial adjustment model and time-varying parameter models, constructed for this purpose, and the consumption sub-models for each of these grain usages.

(4) To develop and test a simulation model for grain import demand in China for the projection period of the next two decades. The simulation model is based on grain consumption demand and grain production. This includes a component simulating feed grain demand, which is based on an assessment of feed grain requirements in different scenarios relating to the different production modes of backyard production. Sensitivity analysis involves alternative specifications regarding key model components. The importance of backyard livestock production and its special feed practices will be emphasized in the simulation model. On the feed grain supply side, the simulation will consider possible changes of technology and policy on grain production, but this component of the analysis will largely be derived from other studies.

(5) To assess the economic and policy implications for Canadian agriculture, derived from the above analysis, considering that China is undergoing a "livestock revolution."[3]

1.3 Organization of the Study

This study has seven chapters in total. In the second chapter, previous methodologies used in predicting China's grain consumption, production, import demand and feed grain demand are reviewed. This review focused on an assessment of why prediction results differ so much from each other. Assumptions behind different estimation models are examined.

In the third chapter, partial adjustment methods are used to estimate grain demand during the period from 1952 to 1999. Long-run and short-run income and price elasticities of demand are estimated.

In the fourth chapter, a time-varying parameter model is proposed and applied to estimate grain demand during the period from 1952 to 1999. A comparison of the prediction results of the partial adjustment and time-varying parameter models is carried out. The model with the best prediction results is selected and its estimated parameters identified for use in the simulation analysis.

In the fifth chapter, different modes of production that exist in China's livestock sector are outlined and possible future changes in social, economic and demographic variables are considered. A simulation model is introduced and estimated. Implications for grain consumption and trade for specific five-

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[3] The term "Livestock Revolution" comes from Delgado, et al, (1999). The term refers to the feature that economic growth and consequent income increases are bringing rapid increases

yearly intervals from 2005 to 2020 are derived from the simulation model and presented.

The sixth chapter provides a review of policy changes that China introduced in preparation for entry to the World Trade Organization (WTO). Recent and prospective patterns of trade flows between Canada and China are outlined and assessed. Trade flows before and after the accession of China to the WTO are briefly compared and possible implications for Canada-China grain trade are assessed.

In the seventh chapter the study is summarized. Implications of the research results to future trade in grain and the world market are discussed, as are suggestions to policy makers. Areas for further research are also noted in this chapter.

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in consumption of meat and milk in many developing countries.

CHAPTER 2 LITERATURE REVIEW: MODELS USED TO PROJECT CHINA'S GRAIN IMPORT DEMAND

2.1 Introduction

Since China plays an important though variable role in the world grain market, considerable research has been undertaken to predict China's grain import demand, both by individuals (e.g., Carter and Zhong, 1991; Huang et al. 2003; Rosegrant and Ringler, 2000; Fuller, 2003; Dong et al. 1995) and organizations (e.g. United States Department of Agriculture [USDA], World Bank, Food and Agriculture Organization [FAO], International Food Policy Research Institute [IFPRI]). Projection methods have varied from the use of large models simulating the global system to simple descriptive analyses. Many descriptive assessments were made by analysts within and outside of China prior to the 1990's and more formal analyses have been conducted since then.

A typical example of a descriptive analysis is given by the projection of Brown (1995) that China's grain demand would be 641 million metric tons while supply would be 272 million metric tons in 2030. This assessment was that China would have a shortage of 369 million metric tons, three times higher than the current total world grain trade level of 99 million metric tons. Brown's projection seems unlikely to happen based on China's agricultural production and consumption performance in the past seven years. The assessment given by Brown does not rely on explicit demand and supply modeling. The projection is primarily based on certain assumptions about growth in population, demand per capita and production. It does not capture interactions among producers, consumers, and government.

Models based on more realistic specifications of demand and supply behavior are more likely to reflect the responses of various decision makers to changes in the economic environment, and interactions among different economic variables. Large simulation models have been constructed, such as World Bank partial equilibrium model, the IFPRI-based International Model for Policy Analysis of Agricultural Commodities and Trade model (IMPACT), and the Country Projections and Policy Analysis (CPPA) model of USDA. Each of these arrived at fairly consistent figures for the levels of production, demand and trade in 2010, despite some differences in assumptions and parameters (Fan and Sombilla, 1997b).

In this section, previous studies that provide quantitative estimates of China's grain production, consumption and trade are briefly reviewed. For the large simulation models developed by organizations, only the estimation results are listed, since detailed descriptions of the structure, and assumptions of these models are provided by Fan and Sombilla (1997(2)). These are usually multi-country, multi-commodity or multi-region partial/general equilibrium models. Generally, they apply information on world and other countries/regions, and different sectors and are the result of many researchers and much effort. Analyses by individual researchers are also reviewed in terms of the model selection, assumptions, nature of the data, and the elasticities that are derived/used in the model.

2.2 Model Review

2.2.1 Model Selection

To date, many previous studies have estimated food demand in China employing either pooled aggregated data (e.g., Lewis and Andrews, 1989; Chern and Wang, 1994; Wu et al. 1995; Gao et al. 1996; Wan 1996, 1998; Fan et al. 1995; Zhang et al., 2001; Davis and Zong, 2002) or household data (e.g., Huang and Rozelle, 1998; Carter and Zhong, 1999; Liu and Chern 2001). The two sets of analyses differ appreciably in terms of methodology employed and estimation results.

PIONEER STUDIES

Few formal statistical studies of demand have been carried out for China. The pioneering study is by Houthakker (1957) where demand for four categories of goods—food, clothing, housing and miscellaneous—was modeled using double-logarithmic approximations on 1927 household data for Beijing and on 1929 data for Shanghai. Formal modelling that yielded estimates of China's grain supply, consumption and trade was undertaken by Tang (1980). This was based on input-output time series data for 1952-77 and was one of the earliest formal estimates of food demand and projections in China. Estimates of the gross value of agriculture output (GVAO) were based on total factor productivity growth (TFP) and two single equations were used to project future aggregate demand and supply. The net trade of grain in 2000 was projected. Because of the data period to which these analyses applied, the results have little relevance today.

ALMOST IDEAL DEMAND SYSTEM

The Almost Ideal Demand System (AIDS) of Deaton and Muellbauer (1980) is widely used in demand analysis when expenditure or budget data are available. Linear expenditure systems (LES) and Rotterdam expenditure systems are also widely used in demand analysis. These models assume that the consumer's utility maximization decision can be decomposed into two separate steps or stages. In the first stage, total expenditure is allocated over broad groups of goods. In the second stage, group expenditures are allocated over individual commodities according to the research objectives. An example of applications of LES and Rotterdam expenditure system models to Chinese food consumption data can be found in research by Lewis and Andrews (1980), and Chern and Wang (1994), respectively

Halbrendt et al. (1994) explored rural Chinese food consumption in Guangdong province using a linearised almost idea demand system (LAIDS). This application was based on 1990 household survey data and added socioeconomic and other demographic variables to the basic AIDS model.

Fan et al. (1995) used pooled provincial and time-series data from 1982 to 1990 to estimate a complete demand system for Chinese rural households. The commodity groups were specified as food, clothing, fuel, housing, and other commodities. Rice, wheat, coarse grains, meat, vegetables, alcohol and tobacco were included in the food group.

Gao et al (1996) combined an upper-level AIDS model and a lower-level general linear expenditure system (GLES) into one estimable system, so that the model conformed to two-stage budgeting but the analysis could focus only on commodities in a single commodity group. Household survey data from Jiangsu province of China were used to analyze consumption of vegetables, pork, beef and lamb, poultry, eggs, fish, sugar, fruit, and grain.

The quadratic AIDS model (QAIDS), which keeps the flexibility of the AIDS model has drawn attention (Fousekis and Revell, 2003) since this has properties of both a flexible functional form and a nonlinear Engel function, and may be particularly appropriate for use with household data (Fisher et al. 2001). Liu (2003) employed the QAIDS model to estimate urban household consumption behavior based on 1998 household survey data.

The AIDS model requires complete price and expenditure data, which are not always available in China. Since the AIDS model uses a flexible functional form to expand the utility function, the number of own- and cross-price elasticities increases with the square of the number of commodities. For adequate degrees of freedom, a relatively large sample size is required.

OTHER MODELS

The inverse demand function allows income elasticities to vary with the level of income. Ito et al. (1989) developed a log-inverse-log model to estimate rice demand in Asian countries. Time series and cross-sectional data were used to analyze domestic demand for rice in Asian countries between 1961 and 1985. The fact that the model ignored substitution effects with other grains was a major limitation since rice and wheat are competitive. The estimates of income elasticities were very low, leading to a conclusion that "rice in Asia is becoming an inferior good" (Ito et. al. 1989, p32).

Dong et al. (1995) developed an econometric model, based on a partial adjustment framework, to analyze Chinese grain import behavior over three decades from the 1960s to the 1990s in order to assess the relative importance of various import determinants. From this analysis, they concluded that major factors influencing grain imports had been changes in state grain procurement policy and associated aspects of China's grain distribution system, and income-related improvements in diet, manifested primarily as a shift from inferior cereals and potatoes to wheat and rice, rather than as feed-grain based increases in meat consumption.

Halbrendt and Gempesaw (1990) chose a stochastic coefficient regression (SCM) approach, developed by Swamy and Tinsley (1991), to generate time-dependent elasticities. This approach accommodates changing structural parameters due to new government regimes. It is argued that the SCM approach can overcome theoretical shortcomings of fixed parameter models in forecasting (Swamy and Conway 1988).

Carter and Zhong (1999) proposed a recursive model based on the agricultural household demand models of Singh et al. (1986), and Strauss and Thomas (1995). This was applied to survey data for 100 households from each of Jiangsu and Heilongjiang provinces for 1993 and 1994. They concluded that in the richer provinces of Jiangsu, the income effect dominated substitution effects, while in the grain-rich province of Heilongjiang, rice was an important substitute to wheat.

EQUILIBRIUM SYSTEM MODELS

Trade models that apply partial equilibrium or competitive equilibrium approaches are another category of models in which demand and trade are linked to prices, and the model solves for the level of prices at which total supply is equal to total demand. These groups of models include global equilibrium and regional equilibrium models. Global equilibrium models are typically partial equilibrium models, in which the prices are generated endogenously to clear the market. Regional equilibrium models usually take world prices as given while domestic prices may be endogenous. One example of a global equilibrium model is the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) developed by Rosegrant, Agcaoili-Sombilla, and Perez (1995) at the International Food Policy Research Institute (IFPRI). This covers 35 countries and regions, and seventeen commodities. The model has been used by Huang et al. (1999), Fan et al. (1997 (1)), among others. The IMPACT model is a global partial equilibrium model, with a focus on the agriculture sector. It is a multi-region, multi-commodity model. Equilibrium world prices for each of the commodities are endogenously determined by market clearing condition.

The Economic Research Service, United States Department of Agriculture (USDA/ERS) developed a Country Projections and Policy Analysis (CPPA) model as another multi-commodity, multi-country partial equilibrium simulation model focused on the agricultural sector. The CPPA China model is documented by Colby et al. (1997).

Comparison of these simulation models is given by Fan and Sombilla (1997b), and Qu and Barney (1999). The point is made that these are synthetic models in which price elasticities are usually taken from other countries with similar conditions or as estimated by other researchers. There are problems of consistency and accuracy in the treatment of China reflecting problems of consistency and availability of China's data. A summary of model structures, assumptions and estimation results, based on Fan and Sombilla (1997 b), is presented in section 2.3.

2.2.2 Previous Income and Expenditure Elasticity Estimates

Previous research into the demand for grain has generated different estimates of expenditure and own price elasticities of demand. Some studies have shown, rice to have become an inferior good in high income countries in Asia: "Income elasticities declined, and in some cases became negative, between 1961 and 1985 in most of the fourteen Asian countries studied." (Ito et al. 1989, p32) However, several studies of Chinese food demand report relatively large positive income elasticities for food grain (Fan et al. 1995; Huang et al. 1999).

Income elasticity estimates are important in prediction China's future demand. Low estimates of income elasticity lead to more optimistic predictions of China's future grain balances. Carter and Zhong concluded in 1999 (p591): "...per capita rural wheat consumption may not grow very fast in the future and may actually fall. Given that a majority of China's population currently resides in rural areas, this will be an important influence on China's future wheat consumption and possibly imports." Ito et al. (1989, p32) concluded "As a consequence, there is a potential for excess supplies of rice to develop in Asia, putting downward pressure on rice prices".

Estimates of larger positive income elasticities of demand for grain or meat tend to lead to pessimistic forecasts of China's ability to achieve grain self-sufficiency and suggest China will face pressures to import more grain in the future. Fan et al. (1995, p54) concluded, "The expenditure elasticities are lower for grains and higher for meat, tobacco, and alcohol. The results imply a gap between food demand and supply growth. Therefore, China will face pressure to import food."

Table 2-1 lists income and price elasticity estimates for rural households based on analysis of pooled aggregate data for 1982 to 1990 by Fan et al (1995). Income elasticities for rice, wheat, coarse grain and meat are less than 1, and this is the case in absolute value terms for the price elasticity estimates, which indicate that these are normal goods. The price elasticity estimate for rice is larger than for wheat. Only alcohol consumption is expenditure elastic, indicating that this is a luxury good.

In addition to the national-level research of Fan et al (1997(1)) for rural households, other studies focus on data from different Chinese provinces. For example, both Halbrendt and Tuan (1994) and Zhang et al. (2001) apply an AIDS model to estimate rural household food consumption behavior in Guangdong province. Halbrendt and Tuan use cross sectional data (for 1990), while Zhang use panel data (for years from 1986 to 1995) in estimation. These estimates of expenditure and price elasticities are listed in Table 2-2 and are quite different, likely reflecting differences in estimation approach. Meat is a luxury good based on Halbrendt and Tuan's estimation, but a necessary good according to the results from Zhang et al.

Table 2-1 Unconditional Expenditure and Price Elasticity Estimates for Rural China, Selected Categories

Model	Two Stage LES/AIDS1				
Estimated Time Period	1982-1990				
	Rice	Wheat	Coarse Grain	Meat	Alcohol
Rice	**-0.63**	0.17	0.18	0.15	0.04
Wheat	0.19	**-0.54**	0.03	0.17	0.05
Coarse Grain	0.30	0.10	**-0.24**	0.13	0.03
Meat	0.15	0.32	0.03	**-0.31**	0.06
Alcohol	0.04	0.13	0.01	0.09	**-0.36**
Income	**0.50**	**0.77**	**0.26**	**0.9**	**1.16**

Source: Fan et al. (1995).

Other results that arise from different models and different datasets lead to even more variation in results. An example is seen in comparison of estimates from Gao et al. (1996), and Carter and Zhong (1999) for Jiangsu, province based on household consumption behavior. Gao et al. based their estimation on 1990 pooled rural household survey data and used a two-stage AIDS model; Carter and Zhong's estimation was based on 1993 and 1994 aggregated household survey data. They used a two stage least square estimation. Gao et al.'s estimation did not separate grain by category, but in Jiangsu province, grain is mainly rice. Carter and Zhong's estimation concentrated on wheat and rice. Income elasticity estimates for Jiangsu province from Carter and Zhong is -0.37, which is quite different from Gao et al.'s results (0.52 for grain expenditure elasticity estimates).

Table 2-2 Expenditure Elasticity Estimates in Rural Guangdong Province, China, Selected Categories and Selected Year

Model	AIDS				
	Own and Cross Price Elasticities 1990				Expenditure Elasticities 1990
Halbrendt and Tuan[1]	Grains	Meats	Vegetables	Other foods	Expenditure
Grains	-0.23	0.71	0.67	0.66	0.58
Meats	0.13	-0.66	0.08	0.07	1.09
Vegetables	0.03	0.02	0.05	-0.10	0.91
Other foods	0.02	0.00	0.01	0.02	1.21
Zhang, Mount and Boisvert[2]	Own and Cross Price Elasticities 1994				Expenditure Elasticities 1990
Grains	-0.31	0.03	-0.01	0.06	0.26
Meats	-0.03	-0.28	-0.10	-0.11	0.70
Vegetables	-0.04	-0.22	-0.16	0.28	0.37
Other foods	-0.08	-0.19	0.05	-1.07	1.20

Sources: 1. Halbrendt et al. (1994). 2. Zhang et al (2001).

Differences in elasticity of demand estimates for food of urban households are also evident from different studies. Table 2-3 lists estimated price and income elasticity estimates from studies by Wu et al. (1995), Gao et al. (1996), and Liu (2003) respectively. The study by Wu et al. employed a two-stage LA/AIDS model. Gao et al. focused on consumer behavior under a partial rationing system in urban China using a mixed-demand model. The study by Liu, an unpublished Ph.D. thesis, used household survey data rather than the aggregate data used in the research of Gao and Wu. Liu applied a quadratic AIDS model to analyze food consumption behavior in urban households.

Reasons why the estimated income elasticities vary include differences in the type of data used and the specifications of the demand models. This points to the need for sensitivity analysis.

Table 2-3 Price and Expenditure Elasticity Estimates of Demand for Urban Households by Different Researchers, China, Selected Categories and Selected Years

Wu, Li, Samuel (1995)[1]

LA/AIDS	Rice	Pork	Beef	Aquatic/Fish	Egg	Expenditure
Rice	-0.70	-0.58	-	-0.48	0.43	0.98
Pork	-0.16	-0.65	-	0.16	-0.20	1.17
Fish	-0.24	0.72	-	-1.40	-0.43	0.54
Egg	0.31	-0.32	-	-0.47	-0.47	0.54

Gao, Wailes, Cramer (1996)[2]

Rotterdam	Rice	Pork	Beef	Aquatic/Fish	Egg	Expenditure
Grain	-0.36	-0.18	0.19	-	-0.03	-0.26
Pork	-0.10	-0.09	-0.89	-	0.06	0.25
Beef	-0.01	-0.30	0.07	-		0.49
Egg	0.01	0.08	0.20	-	-0.18	0.75

Liu (2003)[3]

QAIDS	Rice	Pork	Beef & Mutton	Aquatic/Fish		
Rice	-1.69	-0.13	-0.02	-0.04	-0.07	1.33
Pork	-0.05	-0.96	0.12	-0.09	-0.08	1.18
Beef & Mutton	-0.03	1.09	-0.99	0.04	-0.29	0.80
Aquatic	-0.06	-0.37	-0.03	-0.71	-0.04	1.42
Egg	-0.02	0.06	-0.06	0.06	-0.57	0.56

1. Wu et al (1995)'s estimation was based on aggregate household survey data in 1990. A two stage LA/AIDS model was developed in the research.
2. Estimates of Gao et al (1996) were based on aggregated annual household survey data from 1987-1991, based on a Rotterdam Mixed Demand System.
3. Estimates of Liu (2003) estimation were based on household survey data from 1992 to 1998. The table lists the estimated income and price elasticities in 1998 based on a quadratic AIDS model

Huang and David (1993) observe that with similar estimation methods, income elasticity estimates from cross-sectional household data tend to be higher than those based on aggregate time-series data. Zhang et al. (2001) compared the single equation approach and complete demand systems, concluding that single equation estimates using aggregate time-series data tend to underestimate expenditure elasticities because they miss substitution effects among goods. It is suggested that a complete demand system model fitted to cross-section data may positively bias estimated expenditure elasticities, leading to a conclusion that estimates based on a complete demand system and panel data could be more accurate.

2.3 Further Comparison and Discussion

2.3.1 Total Grain Balance Sheets

In this section, estimation results of larger simulation models are briefly reviewed. Projections reviewed here are by authors, USDA/ERS (1997), "International Agriculture Baseline Projections to 2005"; World Bank (WB) by Mitchell et al. (1997), "The World Food Outlook"; FAO (1995), "World Agriculture: Towards 2010"; OECD (1995), "Chinese Grain and Oilseed Sectors: Major Changes Under Way", IFPRI by Rosegrant et al. (1995) “Global Food Projections to 2020: Implications for Investment”; FAPRI (1997), “World Agricultural Outlook 1997”; Fan and Sombilla (1997(1)), entitled "China's Food Supply and Demand in the 21st Century: Baseline Projections and Policy Simulations"; Huang et al. (1999), "China’s Food Economy to the Twenty-first Century".

Models used by the above organizations are synthetic in that the elasticities used are derived from other studies. In each case the income elasticities of demand used for meat and feed are positive and indicate relative responsiveness to growth of income, implying appreciable increase in demand for indirect grain consumption with income growth.

Differences can arise from model structure—for example static versus recursive models. Static models provide results for a certain time period, but do not describe the process of adjustment, which is the approach of a recursive model. Some of the models that have been tested differ in the timeframe of projections, from a medium term (5-10 years) to the long term (eg. 15-30 years).

We move to assess results of the single sector models of grain production, usage and import demand for China undertaken in 1995 to 1997. The data used in these analyses are primarily China's official data from the State Statistical Bureau (SSB), as well as data from USDA and FAO. Grain production data from SSB show higher production levels than the other two sources, since tubers are considered as grain by the SSB. The way in which rice is included in total grain is another reason for the differences in data from different sources. USDA measures rice in milled form. Both SSB and FAO report the paddy form of rice, but FAO converts the paddy form to a milled measure by applying the conversion ratio of 65%. The definitions of grain from these three sources are listed in Appendix 1.

In comparing the results from the various studies, FAO's reported grain quantities for China are adjusted upward by 1.06 while results based on SSB data are adjusted downward using a factor of 0.85. The FAPRI feed grain quantities are adjusted upward by a factor of 1.07. These conversion factors are adopted based on average differences among production data reported by these different agencies during the 1990s.

Fan et al. (1997(1)), Huang et al. (1997), Mitchell et al. (WB, 1995) and FAPRI (1997) use the USDA grain definition. OECD and OECF use the definitions of Chinese agencies. IFPRI uses the FAO database. The results have been adjusted as noted above to place all estimates on the same definitional basis.

Table 2-4 Projections of Grain Production in China by Selected Studies in Selected Years, Units: million metric tons

Year	USDA 1997	WB 1995	OECD 1995	FAPRI 1997	IFPRI 1995	FAO* 1995	Fan et al, 1997(1)	Huang et al, 1997	**Actual 2000**
Avg. 90-95	362	362	362	362	362	362	362	362	**362**
2000	**382**	**377**	**419**	**380**	*407*	**398**	*375*	**367**	**345.1**
2005	**419**	*410*	*476*	**405**	*452*	*434*	*399*	*392*	
2010	*456*	**443**	*533*	*430*	*497*	*470*	**417**	**421**	
2020					**540**		**449**	**491**	

Source: Adapted and extended from Fan and Sombilla (1997(2)). The date stated for each source is the publication year of the authors' projections.

Table 2-4, Table 2-5 and Table 2-6 present the adjusted projection results on production, demand and trade from the different models. The figures for 1990-1995 and 2000 are the actual levels. The italicized figures are simple moving averages, which have been calculated to give comparable figures for the prediction year. The bold number is the original prediction. The regular number gives actual data based on Economic Research Service, United States Department of Agriculture publications.

The production levels predicted for 2000 by various studies range from 375 to 419 million metric tons. Projection results by USDA (1997), WB (1997), FAPRI (1997), Fan and Sombilla (1997(1)) and Huang et al. (1999) are very close, despite differences in the assumptions underlying the analysis. Grain production was estimated to continue to grow from 1.0 to 1.1 percent annually in the period from 1995 to 2010. However, in 2000 China suffered the most serious drought in 20 years, adversely affecting 30.7 million hectares (75.9 million acres) of farmland in the main grain-producing areas of northern and northeastern China (Farmer's Daily, 2000). As a result, the total amount of grain produced in China in 2000 was 345 million metric tons, a reduction of some 40 million tons below expected levels. The annual rate of increase was 1.8 percent during the period from 1990 to 2000. It is estimated that corn output was reduced by 22% in 2000 to 105 million metric tons while wheat production fell by 11.7% to 102 million metric tons (USDA, 2000). The grain demand projections in the studies reviewed here range from 380 to 450 million metric tons in year 2000 (Table 2-5). The variation is much larger than in the production projections. The projections of Mitchell et al. (1995) and Fan et al.(1997) show the lowest rate of increase in grain demand at 1.5 per cent per year, such that grain demand was expected to be only 380 or 389 million metric tons, respectively, in 2000. Huang et al. (1999) provide the largest demand projection of 425 million metric tons, in 2000. The annual growth rate that these authors projected was approximately 3 percent per year. Other demand projections for 2000 were around 390 to 420 million metric tons. Actual grain demand at the end of 2000 was estimated to be 379 million metric tones (USDA 2001), which is close to the lowest projection level. It seems that most, though not all, projection studies tended to overestimate grain demand for China in the year 2000.

Table 2-5 Projections of Grain Demand in China from Selected Studies, Units: million metric tons

Year	USDA 1997	WB 1995	OECD 1995	FAPRI 1997	IFPRI 1995	FAO 1995	Fan et al, 1997 (IFPRI)	Huang et al, 1997	**Actual 2000**
Avg. 90-95	345	345	345	345	345	345	345	345	**345**
2000	**400**	**389**	**445**	**404**	*392*	**415**	*380*	**450**	**378.8**
2005	**445**	*427*	*492**	**437**	*437*	*485*	*415*	*480*	
2010	*490*	**464**	*545**	*470*	*482*	*555*	**450**	**513**	
2020					**532**		**490**	**594**	

Source: Adapted and extended from Fan and Sombilla (1) (1997). The date stated for each source is the publication year of the authors' projections. *Estimated from annual growth rate.

Table 2-6 Projections of Net Grain Imports by China by Selected Studies, Units: million metric tons

Year	USDA 1997	WB 1997	OECD 1999	FAPRI 1997	IFPRI 1995	FAO 1995	Fan et al, 1997 (IFPRI)	Huang et al, 1999	**Actual 2000**
Avg. 90-95	-17	-17	-17	-17	-17	-17	-17	-17	**-17**
2000	**18**	**11**	**26**	**25**	*-15*	*17*	*15.5*	**21**	**-7.8**
2005	**26**	*17*	*16*	**32**	*-15*	*51*	*27.8*	*22*	
2010	*34*	**22**	*12*	*40*	*-15*	*85*	**33**	**24**	
2020					**-8**		**41**	**27**	

Source: Adapted and extended from Fan and Sombilla (1) (1997). The date stated for each source is the publication year of the authors' projections.

The import demand projections from previous studies, reported in Table 2-6 represent the gap between import and export projections. Variation in predicted import demand comes from variations in estimates of supply and demand, which reflect optimistic or pessimistic forecasts of the various authors relative to China's future grain supply and demand. From Table 2-6, all projections, except for IFPRI, forecast net imports that range from 11 to 25 million metric tons in 2000. The actual trade data from 1996-2000 do not support the existence of large grain imports (USDA, various years). If the economists' projections cited above were true, there might have been over-prediction of demand or it might have been that the government used stocks to balance grain demand and supply.

2.3.2 Projection of Feed Grain Demand

Besides direct food grain consumption, feed grain consumption now represent one of the largest uses of grain in China, accounting for one third of total consumption (USDA). It is expected to continue to increase with rapid increases in per capita income. China's direct grain consumption is comparatively high among Asian countries (Huang and David, 1993). Thus, future increases in per capita consumption can be expected to come mainly from increased indirect grain consumption, through meat consumption demand. To project correctly future grain import demand, the correct projection of feed grain consumption demand is important.

To predict feed grain demand, the most common method is first to predict the demand for meat. Multiplying meat demand by a grain-meat conversion ratio results in feed grain demand estimates. The grain-meat conversion ratio that is adopted is crucial to this method. Grain-meat conversion ratios used in predicting China's feed grain demand are listed in the Table 2-7.

The studies by Carter et al (1988) and Huang et al (1999) project demand for meat and apply a grain-meat conversion ratio to develop feed grain demand estimates. In both these studies, per capita consumption levels are first predicted and then multiplied by population numbers to obtain estimates of the national level of grain consumption. Feed demand is calculated by multiplying feed conversion coefficients by livestock production levels to obtain a total demand for feed. The conversion coefficient used by Carter and Zhong is 4; that is, four kilograms of grain are assumed to be needed to produce one kilogram of meat. The authors do not provide specific references in support of their use of this number, although for the United States, as reported by the USDA Economic Research Service (ERS) the grain-meat conversion ratio for pork was estimated at 4 in 1983 and 3.93 in 1990. This figure has shown a gradually decreasing trend. However, China has had a long tradition of using non-conventional feed resources (NCFR) to feed livestock. A grain-meat conversion ratio of 4 is inaccurate for China as the typical ration includes substantial non-grain energy sources.

Table 2-7 Grain-meat Conversion Ratios Used in Selected Studies
Units: kg of grain /kg of meat production

Organization/Models	Pork	Poultry
Carter & Zhong (1988)[4]	4	4
USDA (1997) (CPPA model)	3.484	2.092
OECD (1995)	4.5	2.7

It is evident that the grain-meat conversion ratio used by Carter and Zhong (1988) follows western standards, and is high for China. This could be a reason for the overestimation of demand. If a grain-meat conversion ratio of 3 had been used instead of 4, the predicted feed grain demand in 2000 would have been 104 mmt, closer to the actual feed demand of 103 (Table 2-8).

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[4] In Carter & Zhong's estimation, the conversion ratio was taken as 4 for all meat. Categories of livestock are not differentiated.

Table 2-8 Projections of Food and Feed Grain Demand for China by Carter et al. and Huang et al., Units: million metric tons

	Carter and Zhong			Huang et al			Actual	
	Foodgrain	Feed	Total	Foodgrain	Feed	Total	Feed	Total
1990	**338**	**81**	**432**	269	59	322	59	322
1995	**360**	**108**	**487**	279	83	357	85	357
2000	**379**	**139**	**544**	**341**	**109**	**450**	103	375
2010	*414*	*228*	*692*	**355**	**158**	**513**		
2020	*452*	*371*	*913*	**362**	**232**	**594**		

Source: Carter and Zhong (1988), Huang et al (1997) and USDA/ERS for the actual number.

In addition to the high grain-meat conversion ratio adopted by Carter and Zhong, there are other two major problems in their model: First, the assumption that consumption this year is a linear function of income and consumption last year [$C_t = a_0 + a_1 I_t + a_2 C_{t-1} + e_t$] can be criticized. This implies that meat consumption will increase linearly and unlimitedly if a_i is positive (as in their model) and ignores the important variable of price. Taking meat consumption of urban residents from 1991 to 1995 as an example, per capita meat consumption decreased at an annual rate of 3% during this period, despite the fact that income increased at an annual rate of 8.2% (Table 2-9), due to the rapid increase of pork prices. It is also observed that aquatic product consumption increased at an annual rate of 3.5% percent during this period. The figures in Table 2-9 reflect that meat consumption varied according to relative price changes. When income increased, consumers tended to increase more aquatic product consumption. There are evidently substitution effects for fish and meat consumption.

A second issue in the study by Carter and Zhong (1988) relates to time series analysis and the lack of checking the unit root of the variables, due to more limited econometric knowledge of 1991. Current procedures in using time series data are to check the unit root for each of the variables to make sure all the variables are stationary to avoid spurious results. Since researchers using traditional econometric testing procedures are likely to find spurious relationships among totally unrelated non-stationary series (Granger and Newbold, 1974). Income and price variables often have unit root problems since the series may show a stochastic pattern around a rising trend. Using the log form, growth rates, or differences to make data series stationary are common methods to deal with this problem for an income series. Price series may exhibit random walk. First differencing is the common method to deal with this issue. One should not use income and price directly without first checking the unit root (Harvey, 1990).

Table 2-9 Changes in Income, Meat/Aquatic Consumption and Prices Per Year, China, 1992 to 1995, Units: percentages

	Meat		Aquatic Product		
	Consumption	Price	Consumption	Price	Income
1992	-3.56	7.31	2.12	8.10	8.97
1993	-3.04	14.68	-2.08	22.09	10.21
1994	-2.60	52.41	6.36	22.19	8.78
1995	-2.67	16.19	7.85	12.40	4.93
Average	-2.97	22.65	3.56	16.20	8.22

Source: computed based on data from China's State Statistical Bureau, various years.

Carter and Zhong's model (1988) also has several advantages compared with Huang's model. First, it is a dynamic model. Although the authors do not provide the theoretical background for the model, it is derived from:

$$C^* = b_0 + b_1 I_t \qquad (2.1)$$

$$C_t - C_{t-1} = (1-\lambda)(C_t^* - C_{t-1}) + u_t \qquad (2.2)$$

$$0 < \lambda < 1;$$

Substitute 2.1 into 2.2, define $a_0 = b_0(1-\lambda)$, $a_1 = b_1(1-\lambda)$, $a_2 = \lambda$, then

$$C_t = a_0 + a_1 I_t + a_2 C_{t-1} + \varepsilon_t \qquad (2.3)$$

where C* is the desired level of per capita grain demand, which is a function of income. The relationship between actual and desired level of per capita consumption demand is specified by (2.2). The actual level is adjusted to the desired level by a partial adjustment process. The coefficient a_2 is equal to the rate of adjustment of C_t to C^*. When $\lambda=0$, equation (2.2) is reduced to a static consumption demand form (2.1).

The dynamic model is preferred to a static model, since it assesses the adjustment path to the results. The partial adjustment model is very suitable to describe China's economy, which is a mixture of planning and market economy. Rigidities in institutions and transportation restrictions are factors that may limit consumers' adjustment to desired levels.

Second, Carter and Zhong's (1988) estimate consumption demand of direct grain consumption as food grain, as well as indirect grain consumption—feed grain and other usage of grain for beverage. Other usages of grain are growing. The usage of grain for beverage is the third largest form of grain consumption after food grain consumption and feed grain consumption. Estimation of this part is usually missing in other studies of projected demand.

Third, Carter and Zhong's (1988) model does not have high demand for data. Since the model does not involve the use of a flexible function form, less data are required for reliable results. Only income and consumption data (which are relatively easy to obtain) are needed in Carter and Zhong's model.

2.4 Summary and Conclusion

In this chapter, previous literature on China's grain consumption and demand and some global projection models are reviewed. By adjusting differences arising from the different definitions of grain, the projections for grain production, consumption and import in 2000 are compared. The more accurate models projected that grain production was increasing around 1.1% annually by 1995 and 2000. Most organizational projections fell in this range. Accurate projections of grain demand saw grain consumption increases around 1.5%. However, most studies projected that demand would increase more than 3% annually, leading to large grain import demand by 2000. Over projection of grain consumption demand has been a common problem of all global projection models.

Review of feed grain demand projections found these tending to be almost double the actual level. An over high grain-meat grain conversion ratio is the major reason for over-projection of feed grain demand and total grain consumption demand.

Assessment of global simulation models indicates that these focus on the global grain balance and may not give detailed information about China. Projections from the grain production model of the FAO, for example, did not include China due to insufficient data. Supply for China was predicted[5] from past trends. Country-level models, on the other hand, may lose the connections of a world vision, to concentrate only on the agricultural section but do give a more explicit picture of China's grain production, consumption or trade using limited resources.

While the AIDS model, based on utility maximization theory, is a desired choice for demand analysis, it is less feasible for analysis of China's aggregate grain consumption, having the shortcomings of a static model and being less well-suited for projection[5]. Wang and Bessler (2003) compare the short-term forecasting ability of five demand systems for U.S. meat consumption. Four static demand systems including AIDS and a dynamic Vector Error Correction Model (VECM) are considered. Their conclusion is that, in general, the dynamic VECM model performs best. Carter and Zhong's original 1988 model is a dynamic model, but misses the important factor of price and could not adequately explain future grain consumption.

From review of the projection models, it was determined to develop and use dynamic models with key economic variables to estimate grain

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[5] The Oxford English Dictionary gives the meaning of "Projection" and "Prediction" as: "A *projection* is a *quantitative* estimate, often based on a model, of the future value of a particular aggregate such as population, income, or supply expressed as a point estimate, or a percentage change, or a range of values within confidence intervals. A *prediction* is a *qualitative* forecast or prophecy about a future outcome, for example widespread famine, rising prices, or supply shortfalls".

consumption demand. We select two models for this purpose, a partial adjustment model with price and income as the explanatory variables, and a time-varying parameter model with price and income as time-varying variables.

CHAPTER 3 ECONOMETRIC MODEL: GRAIN DEMAND

In this chapter, an econometric model for the empirical analysis of the demand for grain is specified and tested. Due to differences in the institutional structure of grain consumption in rural and urban areas, separate rural and urban grain consumption models are specified and estimated. The price and income elasticities estimates are derived and reported for long run and short run periods of adjustment and the implications of these estimates for changes in consumption associated with policy changes is discussed.

3.1 Introduction

Since the adoption of the "open door" policy during the 1980s, China has experienced rapid economic growth. This has led to fundamental changes in the structure of human diets, particularly as people have shifted from rural to urban areas. China's earlier grain policy, which used to be called "the fundamental policy" (*Jiben Guoce*), has changed considerably. Grain policy evolved from one of complete central planning, to a "free market" policy and then to a system of partial government control. These changes can be benchmarked by three important years—1978, 1992 and 1994. In 1978, the adoption of the Household Responsibility System in rural areas of China was a signal to rural households that grain policy would change from the centrally controlled system of the "fundamental policy" toward a system that would place reliance on market signals and decisions. The influence of this reform was fundamental: it greatly changed peoples' concepts and behavior from a major focus on production toward more emphasis on consumption.

In 1992, the government decided to more fully liberalize trading in the grain market by eliminating previous policies and procedures of planned price procurement and sales of grain, and by allowing private trade in grain in rural and urban markets. This policy change greatly influenced urban residents, since the price of food could now be decided by market forces. This phase of the opening up of the food grain market did cause some concerns for urban residents, relative to sudden increases in food prices and supply shortages associated with transportation bottlenecks. Consequently, in 1994, the government adopted the "Governor Responsibility System" (GRS), which made provincial governors responsible for safeguarding the food needs of their citizens. The GRS is a supplement to the "fully liberalized" policy, which moves the "market-oriented" policy back to give more emphasis on grain policy that involves partial government control.

In an economy with such rapid policy changes, which is not fully market based, it is reasonable to recognize that consumption levels are unlikely to fully and instantaneously adjust to changes in current market information. It is likely that changes in consumption, in response to policy changes, and new price and income information, are dynamic. To analyze how the past income and price affect current period consumption decisions, a partial adjustment model is initially chosen for use in the current analysis.

3.2 Partial Adjustment Model

3.2.1 Model Introduction

Partial adjustment models are widely used in production economics. They are based on the hypothesis that producers adjust their production dynamically according to previous years' market information, most importantly price. In a dynamic world, past prices influence output in the current period. A simple way of reflecting the effects of previous prices on current period decisions is through expectation processes. Naïve expectations are the simplest expectation process to model. In this framework, the actual price in the current period is assumed to be the price in the next period so that producers make production plans for the subsequent period based only on the current price.

The use of an adaptive expectations approach assumes that producers consider information from many previous periods in formulating expectations of the current period price. Following Nerlove (1958), the adaptive expectations process can be defined as:

$$P_t^* - P_{t-1}^* = \lambda(P_t - P_{t-1}^*) + v_t \qquad (3.1)$$

where: P_{t-i} = actual price,

P_{t-i}^* = expected price,

λ = co-efficient of expectation, where $0<\lambda<1$,

v_t = error term.

Current period supply can be defined as a function of current period expected price:

$$Q_t = \gamma_0 + \gamma_1 P_t^* \tag{3.2}$$

where: Q_t = current period supply, and

γ_i = supply equation parameters.

The expectations mechanism expressed above can be manipulated, substituted into the supply function, and further manipulated to give:

$$Q_t = \gamma_0\lambda + \gamma_1\lambda P_t + (1-\lambda)Q_{t-1} + v_t \tag{3.3}$$

Here current period supply depends on the actual current period price and the lagged dependent variable. Successive substitution would show current period supply as a function of past prices, and the actual current period price.

A second approach, termed the partial adjustment model, recognizes that there may be institutional rigidities that hamper adjustment to the desired level. For example, although the desired current period inventory depends on the actual current period price, there is a lag in achieving adjustment to the desired level. Nerlove (1958) illustrated this. Here, the adjustment process is:

$$Q_t - Q_{t-1} = \lambda(Q_t^* - Q_{t-1}) + v_t \tag{3.4}$$

where: Q_{t-i} =actual inventory,

Q^*_{t-i} =desired inventory,

λ = co-efficient of adjustment, where $0<\lambda<1$,

v_t = error term.

The supply function is given by:

$$Q_t^* = \alpha_0 + \alpha_1 P_t \tag{3.5}$$

where: α_i = supply equation parameters.

Substituting the supply equation into the adjustment process, and solving for current period supply yields:

$$Q_t = \alpha_0 \lambda + \alpha_1 \lambda P_t + (1-\lambda) Q_{t-1} + v_t \tag{3.6}$$

With both the adaptive expectations and partial adjustment models, a lagged dependant variable is included in the estimating model. The implied lag structure is a geometrically distributed lag (GDL), which has the property that all past prices influence current period output and the weighting on past price declines geometrically over time. The coefficient on the lagged dependant variable indicates the length of the response due to previous price changes. A small value of λ implies that a short period of time is taken to respond to past prices, while a large value of λ indicates that the adjusted response occurs over a longer time period. In one of the two extreme cases, where λ equals 1, equations (3.1) and (3.4) reduce to the static form and the expected value equals current value; when λ equals 0, equations (3.1) and (3.4) represent a random walk process (Granger and Newbold, 1974).

The partial adjustment model can be applicable in demand analysis when consumption cannot fully adjust to desired levels due to the rigidities in institutions or other features that may cause lags in consumption behavior. Such rigidities could arise from institutional rigidities of the marketing system, or because of consumer-level rigidities, such as persistence of consumption habits, lack of knowledge or inability to use substitutes. Partial adjustment models have been widely used in estimating money demand (e.g. Agenor and Khan, 1996; Bose and Rahman, 1996; McGibany, James and Nourzad, 1995; Kabir, 1992; Boughton and Tavlas, 1991; Shiba 1991); electricity demand (Ashraf and Sabih, 1992); and petroleum consumption (Cooper, 2003; Jones, 1993).

In this study a partial adjustment model is initially applied to analyze changes in China's grain consumption. As outlined in the previous section, China's grain market is not fully liberalized and has been subject to fairly frequent policy changes, so that it is reasonable to assume that it takes time for changes in consumption to take effect. The model specification is outlined in the following section.

3.2.2 Model Specification

Nerlove's (1958) partial adjustment model is specified by equations (3.7) and (3.8). Suppose that the relationship between the actual and desired level of per capita grain consumption is specified as:

$$\Delta Q_t = \lambda(Q_t^* - Q_{t-1}) + v_t \qquad (3.7)$$

where λ is the partial adjustment coefficient, $0<\lambda<1$, v_t is a vector of error terms, $v_t \sim N(0,1)$; and $\Delta Q_t = Q_t - Q_{t-1}$; Q_t is the actual level of per capita consumption; Q_t^* is the desired level of per capita consumption.

The desired level of per capita consumption Q_t^* is a function of price, P, and income, *I*, thus for a linear functional form:

$$Q_t^* = f(P,I) = A_0 + A_1 P_t + A_2 I_t \qquad (3.8)$$

Substituting equation (3.8) into equation (3.7), and rearranging gives:

$$Q_t = H_0 + H_1 P_t + H_2 I_t + H_3 Q_{t-1} + v_t \qquad (3.9)$$

Equation (3.9) is the partial adjustment estimation model for grain consumption. Before estimating equation (3.9), the stability of data should be checked (Harvey, 1993). If data used to estimate equation (3.9) are non-stationary, a differenced form of (3.9) should be estimated (Clark and Klein, 1996), that is:

$$\Delta Q_t = H_1 \Delta P_t + H_2 \Delta I_t + H_3 \Delta Q_{t-1} + v_t \qquad (3.10)$$

However, if there is cointegration among Q, P and I, there might be a possibility of over-differencing. If cointegration exists, an error correction model can be estimated to avoid the problem of over differencing (Hamilton, 1994).

Rewriting equation (3.10) in error correction functional form is readily accomplished. Following Clark and Klein (1996), the current consumption level, Q_t, can be expressed as the desired consumption level, Q_t^*, plus the deviation of the actual consumption level from the desired consumption level.

$$Q_t = Q_t^* + u_t \qquad (3.11)$$

Substituting equation (3.11) into (3.7) and rearranging gives:

$$\Delta Q_t = \lambda \Delta Q_t^* - \lambda u_{t-1} + v_t \qquad (3.12)$$

Substituting Q^*, expressed in equation (3.8), into equation (3.12), gives the error correction form of Nerlove's partial adjustment model (Clark and Klein, 1996) as:

$$\begin{aligned} &\Delta Q_t = \lambda \Delta Q_t^* + (-\lambda)(Q_{t-1} - Q_{t-1}^*) + v_t \qquad \text{or} \\ &\Delta Q_t = H_1 \Delta P_t + H_2 \Delta I_t + H_3 (Q_{t-1} - \beta_0 - \beta_1 P_{t-1} - \beta_2 I_{t-1}) + v_t \end{aligned} \qquad (3.13)$$

where

$$\begin{aligned} H_1 &= \lambda A_1 \\ H_2 &= \lambda A_2 \\ H_3 &= -\lambda \\ v_t &\sim N(0,1) \end{aligned}$$

If Q, P, I are non-stationary with unit roots, the first differences of Q, P and I will be stable. If there is cointegration among Q, P, and I, the error term, which is $Q_{t-1} - \beta_0 - \beta_1 P_{t-1} - \beta_2 I_{t-1}$, will also be stable. Equation (3.13) will overcome the problem of over differencing and provide consistent estimates of the parameter (Clark and Klein, 1996). In equation (3.13), the desired consumption level Q_t^* represents the steady state or long-run equilibrium consumption. The coefficients of β represent the long run effects, while H represents the short run relationships.

In estimating equation (3.13), the two-stage estimator suggested by Engle and Granger (1987) is used. The first step is to estimate the long run relationship, given by equation (3.8):

$$Q_{t-1} = \beta_0 + \beta_1 P_{t-1} + \beta_2 I_{t-1} + u_{t-1}$$

using ordinary least square estimation. The error terms, which are:

$$u_{t-1} = Q_{t-1} - \beta_0 - \beta_1 P_{t-1} - \beta_2 I_{t-1}$$

are then substituted into equation (3.13) to estimate the error correction model.

Following the example of Deaton and Muellbauer (1983), the demand functions are specified in double-logarithmic form. The estimated coefficients of price and income variables are the income and price elasticities, respectively. The desired level of per capita consumption of goods *i* (grain, meat or spirits) in period t is expressed as:

$$\log q^*_{it} = \alpha_{i0} + e_t \log x_{it} + \sum_{k=1}^{k} e_{ik} \log p_{kt} + u_{it} \qquad (3.14)$$

where x_{it} is the expenditure on good *i* in period *t*, and *k* refers to goods related to *i*. Since both grain and spirit are each major categories of consumption, and meat is considered as an aggregate commodity, the definition of substitute and competitive commodities is unclear and we ignore other possible related goods. Equation (3.14) takes the following form for estimation:

$$\log q_{it} = \alpha_{i0} + \eta_t \log x_{it} + e_{it} \log p_{it} + u_{it} \qquad (3.15)$$

3.2.3 Data Sources and Explanations

National level aggregate time series data from 1952 to 1999 are used in the estimation. The data are for per capita grain, meat and spirits consumption from 1952 through 1999. Income and consumption data from 1952 to 1982 are taken from Carter and Zhong's (1988) database. Income is defined as real per capita income, which is denominated by the consumer price index (CPI) in each year. Carter and Zhong's database was based on data given in the China's Statistical Yearbook (various years). Data after 1988 are from China's Statistical Yearbook (various issues). Retail Price Indexes by Category of Commodities are used in the calculation of prices. All of the Price Indexes are based on 1950=100. The quantities of net grain imports are calculated from data on imports minus exports. These export and import quantity data are from USDA (2001). A description of the variables is given in Table 3-1. The source data on grain consumption levels for urban residents are originally reported in flour form, while for rural residents, consumption levels are originally reported in raw grain form. A milling ratio of 0.79 is applied to the urban grain figures to transfer these data from flour into raw grain equivalents to obtain national grain demand figures.

3.2.4 Testing the Stability of the Data Series

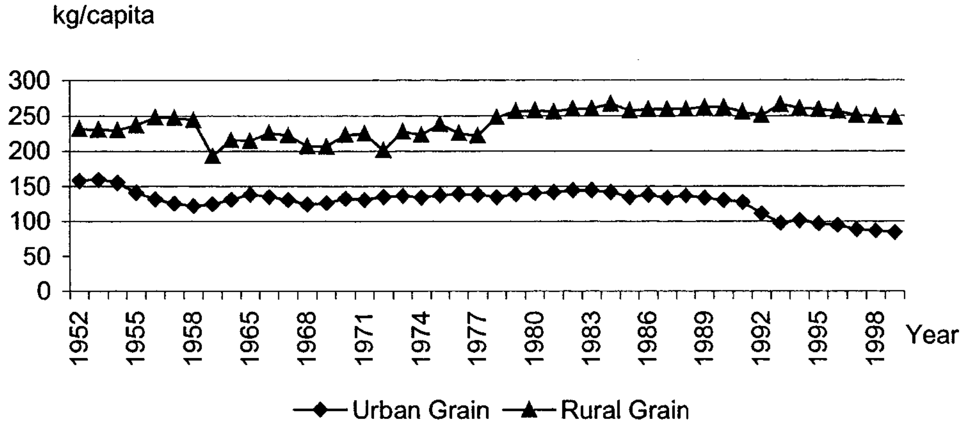
Before applying the error correction model specified in section 3.2.2, unit root tests are conducted to test the stability of the variables (Davidson and MacKinnon 1993). If the variables are non-stationary, estimation results are not stable and may be spurious (Granger, 1987). Because of the length of the time period in this analysis, there could be structural breaks in the data. Consequently the traditional Dickey-Fuller unit root test might lose some power. Thus we use the method developed by Vogelsang and Perron (1998) to test a unit root in a time series with a changing mean. If the series is not stationary, a cointegration test is needed to determine the relationship among the variables (Granger, 1987).

Figure 3-1 shows per capita grain consumption from 1952 to1999. Use of the augmented Dickey-Fuller unit root test shows that the grain consumption series for both urban and rural residents each have unit roots; I(1), that is, the series are non stationary with an unit root. A series with a unit root can be stabilized by differencing once (Granger and Swanson, 1997). This procedure is applied.

Table 3-1 Summary Descriptions of the Data.

VARIABLE	SYMBOL	UNIT	N	MINIMUM	MAXIMUM	MEAN	STD. DEVIATION
Urban Grain Consumption Level	UGR	(kg/capita)	48	85	159	129	18
Price Index of Grain	UPG	(1950=100)	48	113	1151	280	292
Urban Meat Consumption Level	UMT	(kg/capita)	48	2	23	15	6
Price Index of Meat	UPM	(1951=100)	48	110	1269	363	324
Urban Spirit Consumption Level	UST	(kg/capita)	48	2	10	5	3
Urban Price of Spirit	UPS	(kg/capita)	48	112	381	191	79
Urban Income	UI	(RMB/capita)	48	159	854	351	184
Urban Population	UPOP	(100,000)	48	7163	38892		
Rural Grain Consumption Level	RGR	kg/capita	48	186	267	237	23
Price Index of Rural Grain	RPG	1951=100	48	121	1528	397	382
Rural Meat Consumption Level	RMT	(kg/capita)	48	1	16	8	4
Price Index of Rural Meat	RPM	(1951=100)	48	119	1890	514	496
Rural Spirit Consumption Level	RST	(kg/capita)	48	0.38	7	3	3
Price Index of Rural Spirit	RPS	(1951=100)	48	112	323	179	59
Rural Income	RI	(RMB/capita)	48	45	552	194	150
Rural Population	RPOP	(100,000)	48	50319	87017		
Aquatic Product Price Index	AQUA	(1952=100)	48	100	15341	3064	3939
Dummy Variable	D1	1 if year=1952-1978 0 if year=1979-1999	48	0	1		
Dummy Variable	D2	1 if year=1952-1994 0 if year=1995-1999	48	0	1		
Dummy Variable	D3	1 if year=1959-1962 0 if other years	48	0	1		

Figure 3-1 Per Capita Urban and Rural Grain Consumption, China, 1952-99



If there is structural change, the standard unit-root tests will be biased toward non-rejection of the hypothesis of a unit root when the full sample is used. However, if split samples are used, the regressions usually have low power. Following Vogelsang and Perron (1998), the unit root with a changing mean are tested. The test results still do not reject the existence of unit roots. These tests are also applied to meat and spirit consumption data and the results are the similar. Figure 3-2 and Figure 3-3 show the meat consumption and spirits consumption data from 1952 to1999. The test results show that there exist unit roots in both the meat and spirits consumption data sets. Thus, these series are all non-stationary and are stabilized by first differencing.

Identical tests were also applied to the price and income data series. The results of these indicate that the price series for grain, meat and spirits and income series are also I(1); that is, all of the series at issue are non-stationary with unit roots.

Figure 3-2 Per Capita Urban and Rural Meat Consumption, China, 1952-1999

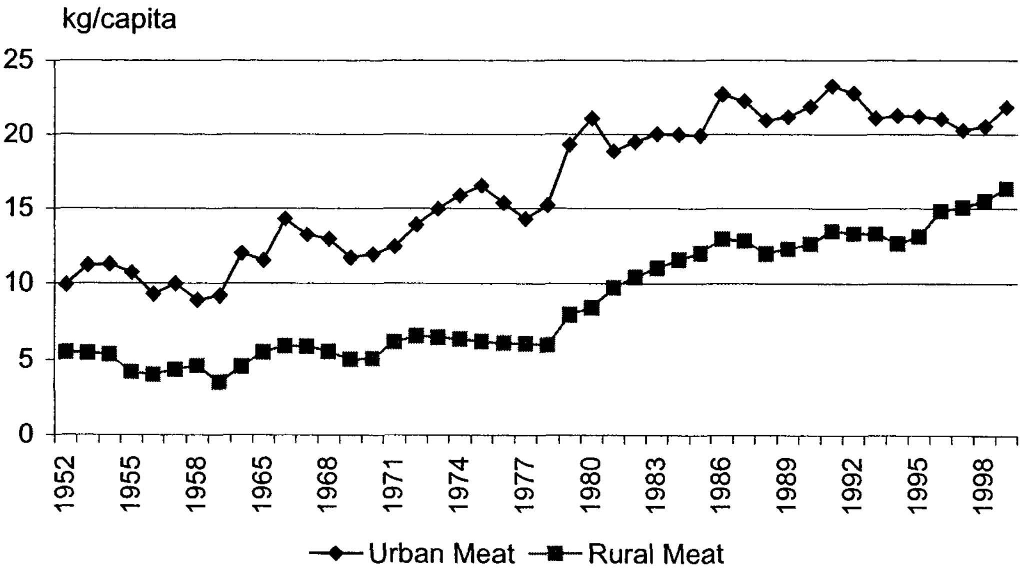
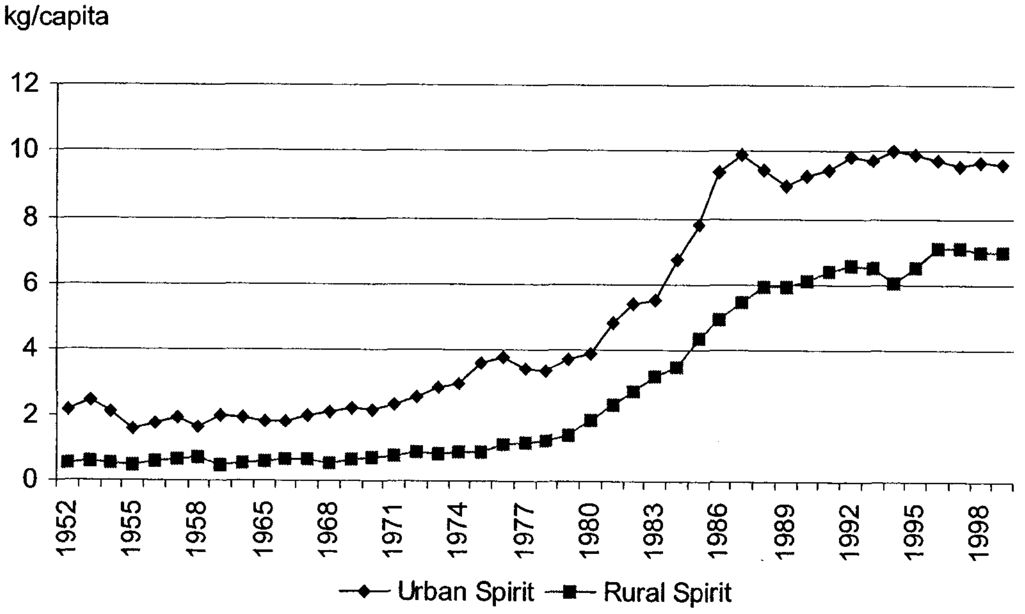


Figure 3-3 Per Capita Spirits Urban and Rural Spirits Consumption, China, 1952-1999



Since all variables are non-stationary and each has a unit root, I(1), co-integration tests are applied to assess whether there are long-term relationships among these variables. Critical values for these tests are obtained from Davidson and MacKinnon (1993).

Table 3-2 Augmented Dickey-Fuller (ADF) Unit Root Tests for Stationarity, 1952-99

Variables	Level/First Diff.	Type of Test	Test Statistic	Conclusion
log(rgr)	Level	ADF	-1.74	
	Fist diff.	ADF	-4.91***	I (1)
log(rmt)	Level	ADF	-1.64	
	Fist diff.	ADF	-5.16***	I (1)
log(rst)	Level	ADF	-0.17	
	Fist diff.	ADF	-5.03***	I (1)
log(ugr)	Level	ADF	-0.46	
	Fist diff.	ADF	-4.25***	I (1)
log(umt)	Level	ADF	-2.4	
	Fist diff.	ADF	-5.70***	I (1)
log(ust)	Level	ADF	-0.04	
	Fist diff.	ADF	-5.69***	I (1)
log(rpg)	Level	ADF	-0.06	
	Fist diff.	ADF	-3.40***	I (1)
log(rpm)	Level	ADF	-0.29	
	Fist diff.	ADF	-4.05***	I (1)
log(rps)	Level	ADF	-0.01	
	Fist diff.	ADF	-4.08***	I (1)
log(upg)	Level	ADF	-0.55	
	Fist diff.	ADF	-2.60**	I (1)
log(upm)	Level	ADF	-0.18	
	Fist diff.	ADF	-4.15***	I (1)
log(ups)	Level	ADF	0.23	
	Fist diff.	ADF	-3.91***	I (1)
log(ri)	Level	ADF	-1.05	
	Fist diff.	ADF	-3.34**	I (1)
log(ui)	Level	ADF	2.24	
	Fist diff.	ADF	-5.51***	I (1)

Note: 1% Critical Value* -3.5778
5% Critical Value -2.9241
10% Critical Value -2.5997

Variable definitions are in Table 3-1. The tests of stationarity are all rejected. The test for existence of unit root is significant at the 5% (1%) significant level, denoted by **(***).

If a test statistic is smaller than the critical value, there is evidence of cointegration. Results of the Johansen-Juselius cointegration test are presented in Table 3-3. The third column (titled "Statistic") gives the Likelihood Ratio test statistic, calculated as:

$$Q_r = -T \sum_{i=r+1}^{k} \log(1-\lambda_i)$$

for r=0,1,......,k-1, where λ_i is the is the i-th largest eigenvalue; Q_r is the trace statistic, which is the Likelihood Ratio test of $H_{1(r)}$ against $H_{1(k)}$.

The Log-likelihood cointegration tests indicate one cointegrating equation at the 5% significance level, which suggests that although many developments can cause permanent changes in the individual elements, there is some long-run equilibrium relationship between the individual components as represented by the linear combination.

Table 3-3 Johansen-Juselius Maximum Likelihood Cointegration Test, Urban Grain Consumption, 1952-99

Trace Statistic Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	38.4688*	24.31
r<=1	r =2	9.3956	12.53
r<=2	r =3	0.6734	3.84

*(**) denotes rejection of the hypothesis at 5%(1%) significance level.
r stands for the number of cointegration vectors.

Specifically, the cointegration test results for the rural consumption data could not reject the absence of cointegration at the 5% significance level. However, we note that the test level is fairly close to the critical value and the sample size is small. We hypothesize that in the longer term, a stable relationship among the variables may apply. The test results are in Table 3-4.

Table 3-4 Johansen-Juselius Maximum Likelihood Cointegration Test, Rural Grain Consumption, 1952-99

Trace Statistic Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	30.3276	34.91
r<=1	r =2	11.7068	19.96
r<=2	r =3	0.65829	9.24

*(**) denotes rejection of the hypothesis at 5%(1%) significance level.
r stands for the number of cointegration vectors.

Table 3-5 Johansen-Juselius Maximum Likelihood Cointegration Tests, Rural Meat and Spirits Consumption, 1952-99

		Rural Meat	
Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	33.67*	29.68
r<=1	r =2	15.87	15.41
r<=2	r =3	2.72	3.76
		Rural Spirits	
Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	51.94*	34.91
r<=1	r =2	20.99*	19.96
r<=2	r =3	5.38	9.24

*(**) denotes rejection of the hypothesis at 5%(1%) significance level.
r stands for the number of cointegration vectors.

Table 3-6 Johansen-Juselius Maximum Likelihood Cointegration Tests, Urban Meat and Spirits Consumption, 1952-99

		Urban Meat	
Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	34.24*	24.31
r<=1	r =2	10.55	12.53
r<=2	r =3	2.64	3.84
		Urban Spirits	
Null	Alternative	Likelihood Ratio	5 Percent Critical Value
r=0	r =1	42.86*	34.91
r<=1	r =2	17.90	19.96
r<=2	r =3	1.96	9.24

*(**) denotes rejection of the hypothesis at 5%(1%) significance level
r stands for the number of cointegration vectors.

The test results for meat and spirits consumption all indicate cointegration among consumption, price and income. The test results are given in Table 3-5 and Table 3-6.

Since all the variables are non-stationary and there is cointegration among consumption levels, price and income, the error correction model, shown as equation (3.13), is estimated. After first differencing, the quantity, price and income data series are all stationary.

3.2.5 Estimation Results

In the first step, the long run or static form of the grain consumption model are estimated using ordinary least squares (OLS). The estimated error from the first step is then substituted into equation (3.13) to obtain the dynamic form of the model, which provides estimates of short-run responses of consumption.

Grain Consumption Model

In the process of estimating the food grain consumption model, evidence of structural break in this model was assessed. Test results for the rural grain consumption model show that there is evidence of a structural break before and after 1978, the year in which the household responsibility reform was implemented in rural China. A dummy variable, D1, which equals 0 before 1978 and 1 after 1978, is therefore included in the rural grain consumption model. The estimated model for rural grain consumption is:

$$\log(Q_t)=a_1+a_2*\log(I_t)+a_3*\log(P_t)+a_4*D1+a_5*\log(I_t)+a_6*D1*\log(P_t) \qquad (3.16)$$

Estimation results for the long run are given in Table 3-7. The ADF test statistic shows there is no unit root in the error term and thus the error terms of the estimation equation are stationary. The estimated income elasticity of food grain demand is 0.40 before 1978 and 0.01 after 1978; the price elasticity estimate is –0.58 before the 1978 reform and -0.01 after the reform.

Table 3-7 Long Run Rural Grain Demand Estimates

Log(RGR)=6.6913	+0.3973*log(RI)	-0.5753*log(RPG)
(0.2425)	(0.0758)	(0.0506)
-1.0725	-0.3943*D1*log(RI)	+0.5618*D1*log(RPG)
(0.3047)	(0.0808)	(0.0747)

Adjusted R-squared	0.4746
Log Likelihood	87.9898
Durbin-Watson stat	1.8182
ADF Test Statistic	-5.2184 (1% Critical Value* -3.5778)

The definition of variables is provided in Table 3-1. Numbers in parentheses are the standard errors.

Error terms from the long run estimation are then substituted into the short run estimation error correction terms (EC). The error correction model for rural grain demand is specified as:

$$\Delta\log(Q_t)= b_1*\Delta\log(I_t) +b_2\Delta\log(P_t)+b_3*EC(-1)+b_4*D1*\Delta\log(I_t)+b_5*D1*\Delta\log(P_t) \qquad (3.17)$$

Results of the error correction version of the model are reported in Table 3-8. The error correction coefficient, which has the expected sign and an estimated value of –0.8363, is significant at the 1% level. The relatively large error correction coefficient suggests a slow speed of adjustment to the long-run equilibrium level. The short run price and income elasticity estimates are calculated from the long run elasticities by multiplying the long run elasticity estimates by λ. The estimated short run income and price elasticity estimates are 0.35 and -0.50 respectively for the time period before 1978. The estimates of these elasticities are close to zero and –0.01, respectively, after the 1978 reform.

The relatively inelastic elasticity estimates for grain consumption with respect to each of income and price in both the short- and long run, suggest that direct food grain consumption is not price and income sensitive.

Table 3-8 The Error-Correction Demand Model of Rural Food Grain Consumption

$$\Delta\log(Q_t)= \underset{(0.1882)}{0.2691}*\Delta\log(I_t) \underset{(0.0799)}{-0.3364}\Delta\log(P_t)\underset{(0.1559)}{-0.8363}*EC(-1)$$

$$\underset{(0.1993)}{-0.2178}*D1*\Delta\log(I_t)\underset{(0.1224)}{+0.3615}*D1*\Delta\log(P_t)$$

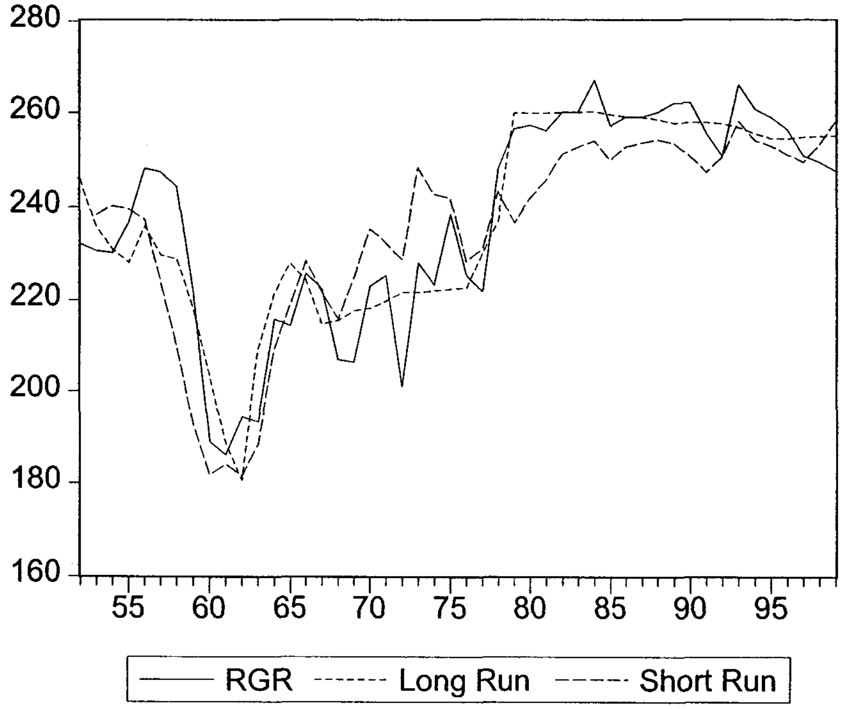
Adjusted R-squared	0.8281
Log likelihood	87.6093
Durbin-Watson stat	1.9271

Note: Numbers in parentheses are estimates of standard errors.

Within-sample predictions of per capita food grain consumption based on the long run estimates from the error correction model are shown in Figure 3-4. The actual levels are shown as the solid line and the predictions are shown as the dotted lines. The desired consumption level, Q_t^*, in Equation 3.8 is not observable but assumed to be determined by prices and income. The predicted long run per capita food grain consumption levels are the predicted long-run equilibrium levels. Figure 3-4 describes the path of predicted short run per capita food grain consumption as this moves toward its long-run equilibrium level.

The long-run prediction line indicates a continuous increase in rural per capita grain consumption since the mid-1960s and a major increase from 1977 to 1985. The predicted levels of per capita grain consumption vary around 254kg/capita after 1985. These changes are closely related to China's agricultural policy. A major decline in per capita food grain consumption occurred from 1958 to 1962, when there were policy changes and consecutive bad harvests led to famine in China.

Figure 3-4 Actual (Solid Line) and Predicted Per Capita Rural Food Grain Consumption (Dashed Line), Kg/capita



The estimated model for urban food grain consumption is:

$$\log(Q_t)=a_1+a_2*\log(I_t)+a_3*\log(P_t)+a_4*D1+a_5*\log(I_t) \qquad (3.18)$$

The long-run estimation results are given in Table 3-9. The ADF test statistic shows no unit root in the error term suggesting the error terms of the estimation equation are stationary. The estimate of the Income elasticity of demand is 0.31 before 1978 and -0.27 after 1978; the estimated price elasticity is –0.13 from 1952 to 1999. The elasticity estimates of price and income are all significant at the 5% level.

The sign on the estimated income elasticity of demand after 1978 suggests that food-grain may have become an inferior good among urban residents in recent years. However, there are relatively few (i.e.22) annual data observations in the post reform period (1978-1999).

Ito, Peterson and Grant's research on rice consumption in Asia (1989) used time-series and cross-sectional data and indicated that rice in Asia is becoming an inferior good with increased income. Income elasticities declined and in some cases became negative between 1961 and 1985 in most of the fourteen Asian countries studied in their analysis. For China, income elasticity estimates by these authors fell during the period from 1961 to 1985, from 0.42 in 1961 to 0.13 in 1985. Wang and Kinsey (1994) examined the effect of strictly rationed housing and partially rationed food grains on consumption and saving behavior for urban households in China from 1981 to 1987. Their estimated expenditure and price elasticities showed that partially rationed food grains in urban households had become an inferior good. Zhang, Mount and Boisvert (2001), in studying the magnitude of the expenditure elasticity for food grain in China, estimated a more complete demand system using a panel of county level data in Guangdong Province for the ten years during the 1990s. These estimates show food grain with a small positive income elasticity, leading to their conclusion that food grain has not become an inferior good in China. Zhang, Mount and Boisvert explained the lack of increase in consumption per capita during a period of rapid economic growth in income as being due to decreases in the relative prices of the food and non-food substitutes for food grain.

Table 3-9 Long Run Urban Grain Demand Estimates

$$\begin{array}{llll} \log(UGR)=3.8702+0.3095*\log(UI)-0.1353*\log(UPG) & & & \\ & (0.6170) & (0.1030) & (0.0582) \\ & 3.4137*D1-0.5868*D1*\log(UI) & & \\ & (1.030) & (0.1767) & \end{array}$$

Adjusted R-squared	0.3960
Log likelihood	91.0047
Durbin-Watson stat	1.9631
ADF Test Statistic	-6.0663 (1% Critical Value* -3.5814)

The definition of variables is in Table 3-1. Numbers in parentheses are the standard errors.

Gardiner and Dixit (1986) noted there are typically differences in elasticity estimates derived from different research approaches and data sets. It has been noted that income elasticity estimates for rice estimated from cross-sectional household-level data tend to be higher than those based on aggregated time-series data (Huang and David 1993 p108), such as used in this study. Research based on more detailed and disaggregated data would be helpful to confirm a conclusion that food grain may have become an inferior good for urban residents.

The error correction model for urban grain consumption demand is specified as:

$$\Delta\log(Q_t)= b_0+b1*\Delta\log(I_t) +b_2\Delta\log(P_t)+b_3*EC(-1)+b_4*D1+b_4*D1*\Delta\log(I_t), \qquad (3.19)$$

The estimation results are in Table 3-10. Estimated short run income and price elasticities are 0.11 and –0.04 respectively for the time period from 1952 to 1978. The estimated income elasticity of demand is again negative, with an estimate of –0.07, for the period after 1978. The estimated income and price elasticities of demand for urban food grain demand are relatively inelastic both in the short run and long run and smaller than the income and price elasticities for rural residents, indicating that direct food grain consumption by urban consumers is less sensitive to price and income changes than for rural residents. The estimated error correction coefficient equals –0.34.

Table 3-10 The Error-Correction Demand Model of Urban Food Grain Consumption

$$\Delta\log(Q_t) = \underset{(0.0083)}{-0.0127} + \underset{(0.1381)}{0.3317}*\Delta\log(I_t) \underset{(0.0614)}{-0.1168}\Delta\log(P_t) \underset{(0.0969)}{-0.3449}*EC(-1)$$

$$+\underset{(0.0158)}{0.0109}*D1 \underset{(0.2586)}{-0.5224}*D1*\Delta\log(I_t)$$

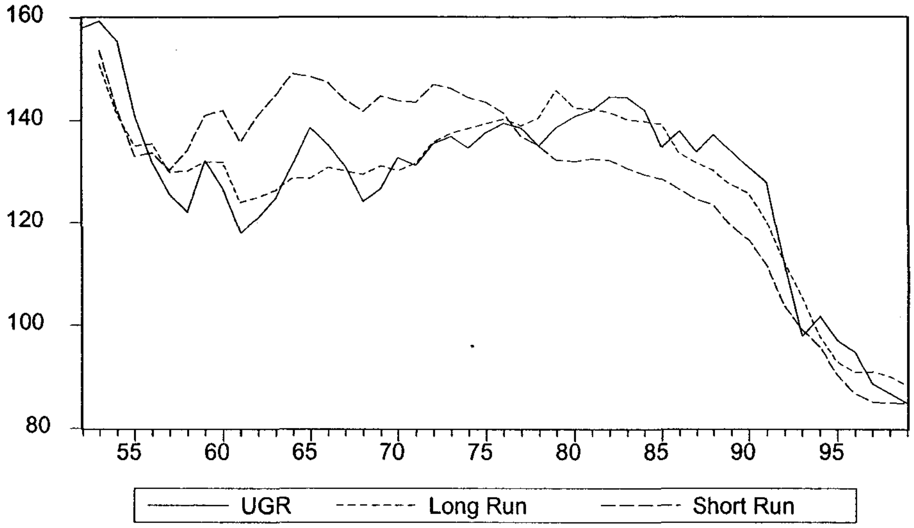
Adjusted R-squared	0.2950
Log likelihood	90.4400
Durbin-Watson stat	1.8612

Note: Numbers in parentheses are estimates of standard errors.

The within-sample predictions of per capita urban food grain consumption based on the long run estimates from the error correction model are given in Figure 3-5. As previously, the solid line indicates actual levels and the dashed lines indicate short and long-run predictions.

The long-run predictions indicate a continuously decreasing trend in urban per capita grain consumption after 1983. Per capita food grain consumption decreased from 143kg/capita in 1983 to 83kg/capita in 1999. The most obvious difference between Figure 3-4 and Figure 3-5 is that there is less volatility in urban grain consumption before the reform period, from 1978 to 1987. The level of grain consumption for urban consumers was relatively stable at about 135 kg/capita in the time period from 1949 to 1987, reflecting government controls over urban grain consumption during that period. Government efforts to stabilize urban consumers' consumption included quotas, price subsidies and other methods. Since 1988, urban grain consumption per capita has fallen appreciably. This is likely to reflect dietary changes as incomes have increased and as the market has been able to adjust in line with preferences. Appreciably more meat is now being consumed by urban residents.

Figure 3-5 Actual (Solid Line) and Predicted Per Capita Urban Food Grain Consumption (Dashed Line), Kg/capita



Meat Consumption Models

Similar procedures as detailed above to estimate demand for directly consumed grain are used in estimating the demand for meat and spirits consumption. The estimation model for rural meat consumption is:

$$\log(Q_t)=a_1+a_2*\log(I_t)+a_3*\log(P_t)+a_4*D3 \quad (3.20)$$

Dummy variable D3 is specified as 0 other than for the years 1958 to 1962, when there were policy changes6 and famine in China associated with consecutive bad harvests. The long-run adjustment estimation results are

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[6] In the years 1958 to 1962, China adopted a series of goals that were incompatible with economic development. The corresponding policies adopted in that time period caused resource wasting and famine.

given in Table 3-11. The ADF test statistic shows that the error terms of the estimation equation are stationary. The estimated income elasticity of demand for meat is 0.71. The price elasticity estimate is –0.12.

Table 3-11 Long Run Rural Meat Demand Estimates

$$\begin{array}{llll} \log(RMT)=-0.8250 & +0.7147*\log(RI) & -0.1220*\log(RPM) \\ \quad (0.1492) & \quad (0.0696) & \quad (0.0662) \\ \quad -0.8001*D3 & & \\ \quad (0.0816) & & \end{array}$$

Adjusted R-squared	0.9581
Log likelihood	33.0475
Durbin-Watson stat	1.6484
ADF Test Statistic	-5.9869 (1% Critical Value* -3.5778)

The definition of variables is in Table 3-1. Numbers in parentheses are the standard errors.

The error correction model of demand for rural meat consumption is specified as:

$$\Delta\log(Q_t)= b_0+b_1*\Delta\log(I_t) +b_2*EC(-1)+b_3*D3*\Delta\log(I_t)+ b_4*D3*\Delta\log(P_t), \qquad (3.21)$$

The estimation results are in Table 3-12. The estimated error correction coefficient, which equals –0.31, suggests a relatively fast rate adjustment. Estimated short run income and price elasticities of demand for meat are 0.22 and –0.03 respectively.

Predictions of per capita rural meat consumption, based on the long run estimates from the error correction model, are given in Figure 3-6. Predicted rural meat consumption increases continuously from 1978, which is the year that the Household Responsibility System was adopted in rural China. Per capita meat consumption increased from 5kg/capita in 1978 to 16kg/capita in 1999. The annual rate of increase during this period is 10.4 percent, which is 10 times higher than in the pre-reform period from 1952 to 1978, when the annual rate of increase in meat consumption was 0.86%.

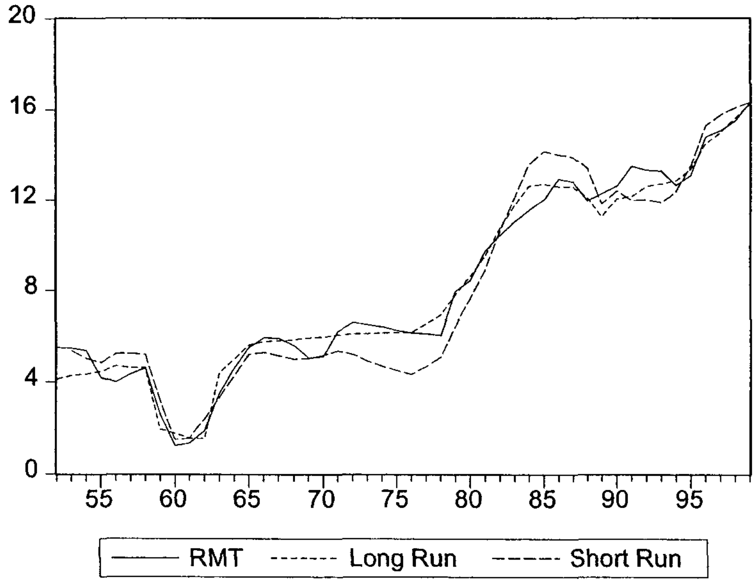
Table 3-12 The Error-Correction Demand Model of Rural Meat Consumption

$$\Delta\log(Q_t) = -0.0336 + 1.2395^*\Delta\log(I_t) - 0.3094^*EC(-1)$$
$$(0.0176) \qquad (0.1844) \qquad (0.1257)$$
$$+5.2470^*D3^*\Delta\log(I_t) + 4.2953^*D3^*\Delta\log(P_t)$$
$$(0.7517) \qquad (0.6967)$$

Adjusted R-squared	0.8122
Log likelihood	49.5324
Durbin-Watson stat	1.9215

Note: Numbers in parentheses are estimates of standard errors.

Figure 3-6 Actual (Solid Line) and Predicted Per Capita Rural Meat Consumption (Dashed Line), Kg/capita



The OLS demand estimates for urban meat consumption, based on the long-run model of equation (3.20), are given in Table 3-13. Subsequent Table 3-14 presents the short-run estimates from the error correction version of the model (equation (3.21)). The estimated long run income elasticity estimate for urban meat consumption is 1.21 and the own price elasticity estimate is -0.45. Urban meat consumption is income elastic and income growth is the major force leading to increased consumption of meat. The estimated short run income and price elasticities for urban meat consumption are 0.36 and –0.13 respectively. Urban meat consumption is not income or price elastic in the short run.

Table 3-13 Long Run Urban Meat Demand Estimates

log(UMT)=-1.7115	+1.2100*log(UI)	-0.4467*log(UPM)
(0.3783)	(0.1526)	(0.1025)
-1.1190*D3		
(1.1190)		

Adjusted R-squared	0.9278
Log likelihood	25.9023
Durbin-Watson stat	1.8326
ADF Test Statistic	-3.9347 (1% Critical Value* -3.5778)

The definition of variables is in Table 3-1. Numbers in parentheses are the standard errors.

Table 3-14 The Error-Correction Demand Model of Urban Meat Consumption

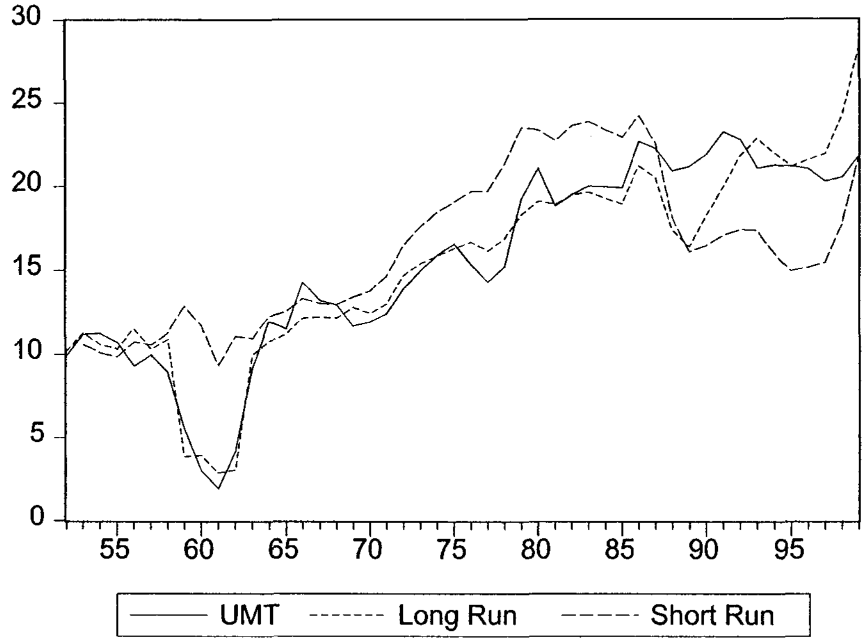
$\Delta\log(Q_t)= 0.0173$	$+0.8830*\Delta\log(I_t)$	$-0.6300*\Delta\log(P_t)$
(0.0448)	(0.6556)	(0.3564)
-0.2947*EC(-1)		
(0.2326)		

Adjusted R-squared	0.1387
Log likelihood	7.3620
Durbin-Watson stat	0.9647

Note: Numbers in parentheses are estimated standard errors.

Predictions of per capita urban meat consumption from both the error correction and long run consumption versions of the model are shown in Figure 3-7. Predicted urban meat consumption demand follows a continuously increasing trend from 1964 to 1999. The major decline in predicted per capita urban meat consumption, from 1958 to 1962, occurred during the period of the Great Leap Forward (Footnote 1). The temporary decline in predicted per capita meat consumption from 1985 to 1990 is associated with comparatively slow increase of income and rapid increase of meat prices during that time period[7].

Figure 3-7 Actual (Solid Line) and Predicted Per Capita Urban Meat Consumption (Dashed Line), Kg/capita



Spirits Consumption Models

The estimated model for rural spirits consumption in the long run is specified as:

$$\log(Q_t)=a_2*\log(I_t)+a_3*\log(P_t)+a_4*D1 \quad (3.22)$$

Estimation results from the long run model are in Table 3-15. The ADF test statistic shows that the error terms of the estimation equation are stationary at 5% significance level. The estimated income elasticity for rural spirits consumption is 1.29, and the price elasticity of demand estimate is –1.21,

---

[7] The annual rate of increase for income from 1985 to 1990 is 4.3%, compared to the rate of increase of 7.8% from 1978 to 1999. The annual rate of increase for meat price from 1985 to 1990 is 14.0%, compared to the rate of increase of 4.80% from 1978 to 1999.

indicating that in the long-run, consumption of spirits by rural consumers is relatively responsive to income and price changes.

Table 3-15 Long Run Rural Spirits Demand Estimates

$$\log(RST)=1.2853*\log(RI)-1.2076*\log(RPS)$$
$$(0.2092) \qquad (0.1848)$$
$$-0.6410*D1$$
$$(0.2314)$$

Adjusted R-squared	0.9181
Log likelihood	-8.5761
Durbin-Watson stat	1.6484
ADF Test Statistic	-2.1398 (5% Critical Value* -1.9480)

The definition of variables is in Table 3-1. Numbers in parentheses are the standard errors.

The error correction model for rural spirits consumption demand is specified as:

$$\Delta\log(Q_t)= b_1*\Delta\log(I_t) +b_2*\Delta\log(P_t)+b_3*EC(-1)+b_4*D1 \qquad (3.23)$$

The estimation results are given in Table 3-16. The estimated error correction coefficient, which equals –0.24, indicates a relatively fast rate of adjustment. Estimated short run income and price elasticities are 0.31 and –0.29 respectively.

Predictions of per capita rural spirits consumption from both the short-run error correction model and the long run OLS model are given in Figure 3-8. Predicted rural spirits consumption increased very quickly after the market reforms of 1978. Predicted per capita spirits consumption increased from 1.2 kg/capita in 1977 to 7.8kg/capita in 1999. Spirits consumption increased to a level about six times the level before the reform, with an annual rate of increase of 9.1 percent from 1978 to 1999, compared to the annual rate of increase at 3.4 percent during the period from 1952 to 1978.

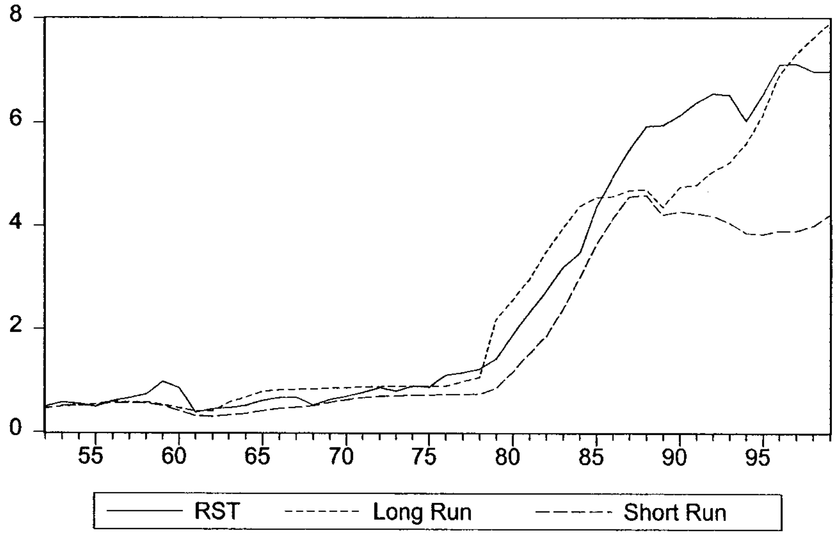
Table 3-16 The Error-Correction Demand Model of Rural Spirits Consumption

$$\begin{array}{llll} \Delta\log(Q_t) = 0.5960*\Delta\log(I_t) & -0.6703*\Delta\log(P_t) & -0.2475*EC(-1) \\ \qquad (0.2420) & (0.5658) & (0.0712) \\ \qquad -0.0628*D1 & & \\ \qquad (0.0380) & & \end{array}$$

Adjusted R-squared	0.3464
Log likelihood	29.6712
Durbin-Watson stat	2.1577

Note: Numbers in parentheses are estimates of standard errors.

Figure 3-8 Actual (Solid Line) and Predicted Per Capita Rural Spirits Consumption (Dotted Line), Kg/capita



The OLS estimates for urban spirits consumption demand in long run and the error correction model of short-run demand adjustments are listed in Table 3-17 and Table 3-18 respectively. The long-run income elasticity estimate for urban spirits consumption is 1.03 and the own price elasticity is -0.17. Urban spirits consumption is income elastic. Income growth is a major force leading to increasing spirits consumption.

The estimated short run income and price elasticity estimates for urban spirits consumption are 0.21 and –0.03, respectively. Urban spirits consumption is not income or price elastic in the short run.

Table 3-17 Long Run Urban Spirits Demand Estimates

$$\begin{array}{llll}
\log(UST)= & -3.8876 & +1.0301*\log(UI) & -0.1734*\log(UPS) \\
 & (0.6463) & (0.2517) & (0.2755) \\
 & +0.5114*D1 & & \\
 & (0.1140) & &
\end{array}$$

Adjusted R-squared	0.9231
Log Likelihood	13.2680
Durbin-Watson stat	0.4378
ADF Test Statistic	-3..0467 (5% Critical Value* -2.9256)

The definition of variables is in Table 3-1. Numbers in parentheses are the standard errors.

Table 3-18 The Error-Correction Demand Model of Urban Spirits Consumption

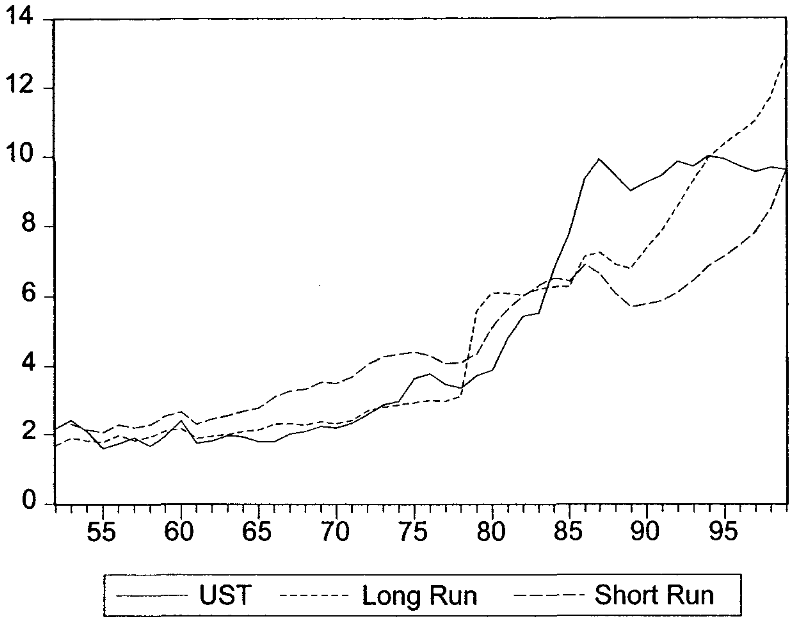
$$\begin{array}{llll}
\Delta\log(Q_t)= & 0.0020 & +0.8944*\Delta\log(I_t) & -0.0430*\Delta\log(P_t) \\
 & (0.0198) & (0.2871) & (0.3384) \\
 & -0.2084*EC(-1) & & \\
 & (0.0815) & &
\end{array}$$

Adjusted R-squared	0.2361
Log likelihood	45.0918
Durbin-Watson stat	1.6887

Note: Numbers in parentheses are estimates of standard errors.

Predictions of per capita urban spirits consumption based on the long-run estimates from the error correction model are given in Figure 3-9. The long-run predictions indicate a continuously increasing trend in urban per capita spirits consumption since 1952. Actual per capita spirits consumption increased from 2kg in 1952 to 10kg in 1999. Per capita urban spirits consumption increased at a rapid rate after the 1978 reforms. The coefficient on the error correction term is -0.21, which indicates a more rapid adjustment to the long-run equilibrium consumption level for urban spirits consumption than is evident for food grain or meat.

Figure 3-9 Actual (Solid Line) and Predicted Per Capita Urban Spirits Consumption (Dotted Line), Kg/capita



3.2.6 Comparison of Income and Price Elasticities

Elasticity estimates for individual commodities may differ due to differences in data, models and estimation periods. It is useful to compare the estimated income and price elasticities reported above with those from other studies. Carter and Zhong (1991) estimated China's demand for total grain consumption using national aggregate data from 1952 to 1982. Huang and Rozelle report estimates based on primary survey data collected in the early 1990s. Fan et al. (1995) estimated a more complete demand system of Chinese rural households for model incorporating a two-stage budgeting system using pooled provincial and time-series data from 1982 to 1990.

In comparison, estimation results reported in the current study are based on national aggregate data from 1952 to 1999, a longer time period of assessment than in the other studies reported in Table 3-19. The summary of results of prior studies listed in Table 3-19, indicates food and meat consumption price elasticity estimates that range from -0.02 to -0.65 and income elasticity estimates that vary from 0.09 to 1.27. As might be expected, expenditure elasticity estimates are lower for food grain than for meat and spirits. All income elasticity estimates for directly consumed food grain are less than one, reflecting the role of food grain as a basic staple. There is evidence from this study that food grain may be becoming an inferior good for urban residents.

3.3 Summary

Partial adjustment models are preferred in demand analysis in situations where consumption cannot fully adjust to desired levels due to rigidities in institutions or other features that may cause lags in consumption behavior. Such rigidities could be caused by such institutional factors as prior contracts and rigidities, asymmetric information, policy restrictions, incomplete markets, or rigidities in consumption habits (Nerlove, 1958). China's grain market is not fully liberalized and has been subject to fairly frequent policy changes, so that it is reasonable to expect that changes in consumption take time for full adjustment. This provides some justification for the use of the partial adjustment model in this study. Due to the non-stationarity of per capita grain, meat, and spirits consumption series, and in the price and income data series, these have to be differenced to make these series stationary. To avoid over-differencing due to the co-integration among consumption levels, prices, and income, the partial adjustment model is estimated in an error correction form.

Table 3-19 Comparison of Estimated Income and Price Elasticities From Prior Studies

	Urban				Rural			
	Food		Meat		Food		Meat	
Author	η	ε	η	ε	η	ε	η	ε
Carter and Zhong	0.14	-0.02	1.16	-0.37	0.37	-0.47	0.97	-0.44
Huang et al[1]	0.09	-0.25	0.83	-0.25	0.25	-0.25	0.76	-0.25
Fan et al.[2]	0.89	-0.65	1.27	-0.38	0.89	-0.65	1.27	-0.38

1.Estimates by Huang et al. for meat price elasticity do not report urban and rural separately.
2.Estimates by Fan, Wailes and Cramer are for rural households and are reported separately for wheat and rice; the grain estimates above attributed to their study are average of wheat and rice.

The income elasticity estimates for rural food grain consumption varied from zero to 0.35 in the short-run estimates and from 0.01 to 0.40 in the long-run, indicating that direct food grains are necessities and normal goods. The estimated income elasticity estimates for urban grain consumption varied from 0.11 (the short run estimate) to 0.31 (the long-run estimate) before 1978 reform, but was negative after the reform. This implies that food grain is becoming an inferior good for urban households. Income elasticity estimates for meat consumption are varied from 0.22 (the short-run estimate for rural model) to 1.21 (the long-run estimate for urban model). Income elasticity estimates for spirits consumption varied from 0.21 (short-run estimates) to 1.29 (long-run estimates). Meat and spirits are relatively more income elastic than food grain. All price elasticity estimates are less than 0.5 in absolute value except for spirits consumption in rural households, where the estimate is -1.21. This suggests that food grain and meat are relatively basic goods in

China whereas spirits are luxury consumption goods among rural households (Table 3-20).

Table 3-20 Estimated Income and Price Elasticities for Grain, Meat and Spirits in Urban and Rural Households, 1952-1999

		Income elasticity		Price elasticity	
		Long run	Short run	Long run	Short run
Grain	Rural				
	1952-1977	0.40	0.35	-0.58	-0.5
	1978-1999	0.01	<0.01	-0.01	-0.01
	Urban				
	1952-1977	0.31	0.11	-0.14	-0.04
	1978-1999	-0.25	-0.07	-0.01	-0.07
Meat	Rural	0.71	0.22	-0.12	-0.03
	Urban	1.21	0.36	-0.45	-0.13
Spirits	Rural	1.29	1.03	-1.21	-0.17
	Urban	1.03	0.21	-0.17	-0.03

Based on the parameter estimates reported here, with future growth of per capita income, increasing total grain demand will arise from growth in indirect consumption of grains, through meat and spirits consumption. Direct per capita consumption of food grain will not increase rapidly due to relatively low estimates of income elasticity. Direct grain consumption per capita in urban households is much lower than in rural households. With economic development, more people will move from rural to urban areas. The urbanization rate is an influence that will decrease direct grain consumption levels. On the other hand, population increase, even at a slow rate, will put pressure to further increase grain demand. The urbanization rate and population growth rate tend to have opposite influences on future grain consumption. In the next chapter, the factors affecting total grain demand in China are further considered.

CHAPTER 4 TIME-VARYING PARAMETER MODEL AND ESTIMATES

4.1 Introduction

This chapter develops and applies a time-varying parameter model to forecast grain consumption demand in China using the same price and income data as for the partial adjustment models in Chapter 3. The results of the time-varying parameter model approach are then compared to the results of the partial adjustment model. Within sample and out of sample predictions obtained from each method are compared to actual data on levels of per capita consumption for food grain, meat and spirits. Predictions are assessed visually (using plotted figures) and statistically (based on the mean square errors of predictions).

The use of time-varying parameter models to estimate grain consumption in China involves application of a state space model using a Kalman Filter algorithm, which allows one or more regression coefficients from a linear model to evolve stochastically, based on the available information. It is argued that this approach has merits even with a small sample size (Harvey, 1993).

4.2 Time-varying Parameter Model

4.2.1 Model Introduction

As Harvey (1993, page 1) suggests, "the main reason for modeling a time series is to enable forecasts of future values." Autoregressive-moving average processes (ARMA) models that contain lagged values of the observed variables and the disturbance term play an important role in dynamic modeling because they allow simple representation of a stationary time series. Models in which observations follow ARMA processes, after the observations have been differenced, are called autoregressive-integrated-moving average (ARIMA) models. Forecasts of local trends can be produced by models from within this class.

An approach to time series forecasting based on ARIMA models was developed by Box and Jenkins (1976), and their model-fitting procedure is referred to as the Box-Jenkins method. Box-Jenkins (1976) type time-series analysis is widely used in economic prediction. With the Box-Jenkins method, the first step in time series forecasting is to achieve approximate stationarity of the data series, by applying various operations such as logarithms and differences. The transformed series is then analyzed and a tentative ARMA specification is chosen. The second step in application of the Box-Jenkins approach is to estimate the model, while the third step is to subject the residuals to diagnostic checking. If the model appears to be satisfactory, it is used for forecasting. If it is not, the whole cycle is repeated (Box and Jenkins, 1976). The partial adjustment model as used in Chapter 3 is a special case of the general ARIMA model (ARMA(0,1)), and the estimation process for that model follows the Box-Jenkins method. However, conventional ARIMA methods with dummy variables to capture policy impacts on the structure of a vector have some limitations as indicated in the following paragraph.

The first problem in the conventional method is that it can be misleading in requiring precision of definition of the timing of the impact of the policy. It is often unclear whether the dummy variable should reflect the timing of the policy announcement, when it came into full effect, or when it was changed or fine-tuned. For example, the Household Responsibility System (HRS) was announced as a policy in 1978, but the full effect of the policy may not have applied in that year or the year after. It may be hard to define a dummy variable to catch the effect of such a policy change. In the analysis using the partial adjustment model, the dummy variable D1, was defined to reflect the introduction of the HRS policy, as 1 after 1978 and 0 otherwise; this procedure may not be sufficiently precise. Second, there is fixity of agricultural assets in agricultural production processes that might cause supply responses to be relatively inelastic while habits in consumption may limit rapid adjustment, leading to gradual adjustments over time rather than abrupt shocks implied by dummy variables. Third, estimation methods that assume fixed coefficients assume constancy in the marginal contribution of causal factors, which may be restrictive in terms of evaluating the impacts of China's evolving policies. Fourth, the time-series database could be viewed as relatively small, in that it contains only 48 years of aggregate data, whereas unbiased estimates are more likely to be achieved from ARMA and other regression models when tested on large samples.

A different approach to local linear trend forecasting is to allow the parameters in the regression model to evolve over time. Such models are called structural time series models. The statistical treatment of structural time series models relies on state space methods, which enable dynamic systems to be represented in the general form known as the state space form (Harvey, 1993). Harvey and Todd (1983) suggest that state space models provide comparable forecasts to the Box-Jenkins approach. Many time series models, including the classical linear regression model and ARIMA models, can be written and estimated as special cases of a state space specification (Harvey, 1993).

Following Granger and Newbold (1986), a state space model can be formulated as one observation equation (indicated below as equation 4.1) and one state equation (equation 4.2). Let y_t be a vector time series with g components, which is to be modeled using given information set I_t. Suppose that there is a finite-order vector of *s* components, denoted by x_t, that fully captures all the information in I_t relevant to modeling $E[y_t \mid I_t]$, so that x_t is essentially a sufficient statistic. The vector x_t is called the state vector and represents the generalized location or state of the system at time t. The basic equations of the state-space representation are:

$$\underset{(g\times 1)}{y_t} = \underset{(g\times s)(s\times 1)}{\beta_t x_t} + \underset{(g\times u)(u\times 1)}{\gamma_t z_t} + \underset{(g\times 1)}{v_t} \qquad (4.1)$$

and

$$\underset{(s\times 1)}{x_t} = \underset{(g\times s)(s\times 1)}{T_t x_{t-1}} + \underset{(s\times L)(L\times 1)}{\delta_t w_t} + \underset{(s\times m)(m\times 1)}{G_t u_t} \qquad (4.2)$$

Equation (4.1) relates y_t to the present value of the state vector x_t plus a vector of other explanatory (exogenous) variables z_t and an error term v_t. The dimensions of vectors and matrices are indicated under each term. Equation (4.2) shows how the forecasts of the state variable can be formed.

> *"The state space form is a powerful tool which opens the way to handling a wide range of time series models. Once a model has been put in state space form, the Kalman filter may be applied and this in turn leads to algorithms for prediction and smoothing" (Harvey, 1993, Chapter 4, page 82).*

The state space model allows unobserved variables (known as the state variables) to be incorporated into, and estimated along with, the observable model. Such models can be estimated using a powerful recursive algorithm known as the Kalman filter. Specifically, Kalman filter methods are applied to accommodate forecasting problems. The Kalman filter is used both to evaluate the likelihood function and to forecast and smooth the unobserved state variables.

A time-varying parameter model is a state-space model with stochastically varying parameters, in which the coefficient vector changes over time. Since the model is linear, the calculation uses the Kalman filter algorithm, which is a way to use all the information in the sample to form the best inference about the unobserved state of the process at any historical date. The state-space model using the Kalman filter approaches gives minimum mean squared error among all other linear estimations (Hamilton, 1994).

Three types of economic models have been suggested as useful candidates for incorporating time-varying parameter approaches (Harvey 1993): behavioural, unobserved causes and small sample. In this study, the approach is applied to an economic model that analyzes changes in grain consumption. Since these results from changes in human behaviour and unobserved influences, time-varying parameter models are suitable for this analysis.

There have been numbers of previous applications of state-space models. Godolphin (2001) demonstrated that these models are useful for describing time series data for forecasting purposes and that there are trend projecting state-space components that can be combined to provide observable state-space representations for specified data series. Godolphin (2001) concluded that the approach is particularly useful for analysis of seasonal or pseudo-seasonal time series. Ueda and Frechette (2002) applied the Kalman filter to test preference changes in milk consumption. Sanz and Gil (2001) approached dynamic estimation using the Kalman filter to assess the impact on Spanish agricultural trade from the entry of Spain into the European Union. Esposti (2000) applied Kalman filter procedures to depict a stochastic process associated with technical change induced by research, development and extension expenditures. Richards, Gao and Patterson (1999) estimated a state-space model using the Kalman filter to evaluate the influence of retail promotion and advertisement to apple demand. Walburger (1998) applied this type of model to analyze local pricing regions for U.S. fed cattle. Doran and

Rambaldi (1997) also applied linear time-varying constraints to demand systems using a state-space model estimated by the Kalman filter.

The methods described here attempt to improve predictions of China's grain demand by estimating the demand for food grain, meat and spirits using time-varying parameter models.

4.2.2 Specification of Time-Varying Parameter Model

Following Harvey (1993), in applying the Kalman filter, we formulate the relevant demand functions in state-space form. Consider a simple relationship between a pair of observed series x_t, y_t of the form:

$$y_t = x_t'\beta_t + w_t \tag{4.3}$$

where the coefficient β_t is allowed to change through time and w_t is the error term. If the changes of the parameter are assumed to follow an AR(1) process, the random coefficients are presumed to be evolving over time according to:

$$(\beta_{t+1} - \overline{\beta}) = F(x_t) \times (\beta_t - \overline{\beta}) + v_{t+1} \tag{4.4}$$

where v_t is the error term and $\overline{\beta}$ is the steady-state value of the coefficient vector, and if the process is stationary and F is a full rank matrix, which are the coefficient matrix of AR(1). If the eigenvalues of the matrix F are all inside the unit circle, then $\overline{\beta}$ is interpreted as the average or steady-state value for the coefficient vector. Defining

$$\xi_t = \beta_t - \overline{\beta}$$

and substituting ξ_t into equation (4.3) and (4.4), the state space model written as:

$$\begin{aligned} \xi_{t+1} &= F(x_t)\xi_t + v_{t+1} \\ y_t &= x_t'\overline{\beta} + x_t'\xi_t + w_t \end{aligned} \tag{4.5}$$

In this case, the state vector ξ_t is assumed to follow a first-order vector autoregressive process. A Gaussian assumption is necessary to preserve the linear structure of Kalman filtering. We assume that $\xi_0 \sim N(\mu_0, P_0)$, $w_t \sim N(0, R)$, and $v_t \sim N(0, Q)$ for t = 0,1, ..., T, and that ξ_0, v_t and w_t are mutually and serially uncorrelated for all t's, Q and R are the variance and covariance matrix for v_t and w_t respectively (Harvey, 1993). In a state space model the system matrices will usually depend on a set of unknown parameters, which are parameters in matrix Q, R and F, and the set of unknown parameters are referred to as hyperparameters. Maximum likelihood estimation of the hyperparameters can be carried out by using the Kalman filter to construct the likelihood function and then maximizing it using a suitable numerical optimization procedure.

In this thesis study estimation, the state variables are the coefficients for price and income, and the state equation is:

$$\begin{bmatrix} \xi_{1t} \\ \xi_{2t} \end{bmatrix} = \begin{bmatrix} \rho_1 & 0 \\ 0 & \rho_2 \end{bmatrix} \begin{bmatrix} \xi_{1t-1} \\ \xi_{2t-1} \end{bmatrix} + \begin{bmatrix} v_{1t} \\ v_{2t} \end{bmatrix} \tag{4.6}$$

where ρ_i is the autocorrelation parameter.

The observation equation is:

$$y_t = c + \bar{c}_p * p_t + \bar{c}_I * I_t + [p_t \quad I_t] * \begin{bmatrix} \xi_{1t} \\ \xi_{2t} \end{bmatrix} + w_t \qquad w_t \sim N(0, \sigma_\varepsilon{}^2) \tag{4.7}$$

Equation (4.6) and equation (4.7) correspond to equation (4.5) if we define ξ_t, R, Q, F and x as:

$$\xi_t = \begin{bmatrix} \xi_{1t} \\ \xi_{2t} \end{bmatrix} \qquad R = \sigma_\varepsilon{}^2 \qquad Q = \begin{bmatrix} \sigma_{1\eta}^2 & 0 \\ 0 & \sigma_{2\eta}^2 \end{bmatrix}$$

$$x_t = \begin{bmatrix} 1 \\ p_t \\ I_t \end{bmatrix} \qquad F = \begin{bmatrix} \rho_1 & 0 \\ 0 & \rho_2 \end{bmatrix}$$

The estimates $\hat{\xi}_{t|s}$ of ξ_t could be *posteriori* estimated recursively by the Kalman filter algorithm as the expectation of the corresponding conditional distribution given the available information of y, the initial distribution of state vector $\xi_0(\mu_0, P_0)$ and the hyperparameters w=($\rho_i, \sigma_{i\eta}, \sigma_\varepsilon$). The vector of hyperparameters w needs to be known. This can be supplied from outside information or estimated by maximizing the log-likelihood function,

$$L_T(w) = \frac{1}{2} \sum \{\log[|D_t(\theta)|] + [D_t(\theta)]^{-1} [y_t - \hat{y}_t(w)]^2\} \tag{4.8}$$

where

$$D_t = Cov[y_t \mid y(t-1); w)]$$

and with respect to the unknown parameters in the matrices of w ($\rho_i, \sigma_{i\eta}, \sigma_\varepsilon$) (Schneider 1991)

Harvey (1988) and Shumway and Katzoff (1991) applied Expected-maximization (EM) methods to derive optimal forecasts. The EM methods can estimate hyperparameters and state variables simultaneously. In this study, the initial values are supplied by OLS estimation and the hyperparameters are estimated by maximizing the log-likelihood function (4.8).

4.2.3 Assessing the Partial Adjustment Model: Parameter Constancy Test

Following Brown et al. (1975) and Harvey (1990, pp. 151-154), plots of the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMSQ) can provide a quick visual test of the structural change, thus to test the stability of the estimated parameters. A recursive test is based on recursive least square estimation. Recursive least squares will generate the same estimates as OLS estimates based on the first t observations (Harvey, 1990). In recursive least squares the equation is estimated repeatedly, using ever larger subsets of the sample data. If there are k coefficients to be estimated in the b vector, then the first k observations are used to form the first estimate of b. The next observation is then added to the data set and k+1 observations are used to compute the second estimate of b. This process is repeated until all T sample points have been used, yielding T-k+1 estimates of the b vector. In each step the last estimate of b can be used to predict the next value of the dependent variable. The one-step ahead forecast error resulting from this prediction, suitably scaled, is defined to be a recursive residual. The recursive residuals are calculated as standardized prediction errors, specifically:

$$v_t = (Y_t - X_t^{'} b_{t-1}) / \sqrt{1 + X_t^{'}(X_{(t-1)}^{'} X_{(t-1)})^{-1} X_t} \qquad \text{for } t=k+1, \ldots, N \qquad (4.9)$$

The CUSUM (cumulative sum) of recursive residuals is:

$$w_t = \frac{1}{\hat{\sigma}} \sum_{j=k+1}^{t} v_j \quad \text{for } t=k+1, \ldots, N, \qquad (4.10)$$

where

$$\sigma^2 = \frac{1}{N-K-1}\sum_{t=K+1}^{N}(v_t - \bar{v})^2 \qquad (4.11)$$

and $\bar{v}$ is the mean of the recursive residuals. The CUSUMSQ (cumulative sum of squares) is:

$$ww_t = \sum_{j=k+1}^{t} v_j^2 \text{ for } t=k+1, \ldots, N \qquad (4.12)$$

The cumulative sum of recursive residuals and CUSUMSQ are estimated and are plotted in Figures 4-1 and 4-2 for the food grain consumption demand model. Comparable figures from the models of meat and spirits consumption are given in Appendix 4. The plots of the recursive residuals are plotted about the zero line. Plus and minus two standard errors are shown at each point. Residuals outside these standard error bands suggest instability in the parameters of the equation or a structural break. CUSUMSQ bounds are stated in Harvey (1990, Equation 2.7). We plot the 5% significance lines. A CUSUMSQ test statistic outside the 5% significance lines indicates that the hypothesis of stability in the parameter of the equation is rejected at the 5% significance level.

In Figure 4-1, the CUSUMSQ test shows that the error terms are within the significance boundary, but the plot of recursive residuals crosses the upper and lower 5% significance line, indicating structural changes in years 1962 and 1963. Plot of recursive residuals in Figure 4-1 also clearly show that the 5% boundary lines are broken by the CUSUM residuals in these two years.

Correspond plots in Figure 4-1 indicate that the assumption of constancy of the estimated parameters, which are the respective income and price elasticities in the long run grain consumption model, is not ideal. In the model for meat, and spirits consumptions, instability of coefficients is confirmed by statistical tests of parameter constancy, using the CUSUMSQ test. The null hypothesis of constant coefficients was rejected for both commodities at the 5% level of significance.

Since the CUSUM plot indicates parameter instability, the assumption of constant parameters as in the partial adjustment model may not be soundly based. To avoid this assumption, state-space models with stochastically varying parameters are tested. This is probably the most frequently applied analysis in situations of parameter non-constancy (Harvey, 1993). The model defined in Equation 4.6 and Equation 4.7 is a time-varying parameter model written in state space form. In the next sector, we use this model to re-estimate income and price elasticities of demand for grain in China.

4.2.4 Estimation Results: Time-Varying Parameter Models

Given that in the time-varying parameter model, the state vector is defined as:

$$\xi_t = \beta_t - \overline{\beta},$$

the vector of the respective means of the estimated coefficients can be written as:

$$\overline{\beta} = \beta_t - \xi_t$$

The vector, $\overline{\beta}$, yields the long term or steady state estimates of the income and price elasticities. The interpretation of these estimates is comparable to the interpretation of the long-run elasticities of demand that were estimated by the partial adjustment model in Chapter 3.

Table 4-1 Estimated Parameters (Including Price and Income Elasticities) of Time-varying Parameter Models (TVP) and Partial Adjustment Models (OLS)

Urban				Rural			
Grain	TVP	OLS1	OLS2	Grain	TVP	OLS1	OLS2
Constant	-1.14***	3.87***	7.28***	Constant	5.17***	6.70***	5.52***
Price	-0.15***	-0.14***	-0.14***	Price	-0.04***	-0.56***	-0.02***
Income	0.34***	0.31***	-0.28***	Income	0.06***	0.38***	0.03***
Meat				Meat			
Constant	-3.99***	-1.71***	-2.83***	Constant	-1.04	-0.83***	1.63***
Price	-0.52***	-0.45***	-0.45***	Price	-0.30**	-0.12***	-0.12***
Income	0.30	1.21***	1.21***	Income	0.41**	0.72***	0.72***
Spirits				Spirits			
Constant	-0.26	-3.89***	-3.37***	Constant	-3.44***		-0.64 **
Price	-0.94***	-0.17	-0.17	Price	-0.55 **	-1.21***	-1.21***
Income	0.88***	1.03***	1.03***	Income	1.43***	1.29***	1.29***

Source: estimated by author. The t test is significant at the 1% (5%) significant level, denoted by ***(**). OLS1 are the estimates before dummy variables are implemented and OLS2 are the estimates after dummy variables are implemented.

The estimated coefficients for time-varying parameter model and partial adjustment model vary in levels. Figure 4-3 provides a plot of the estimated income elasticity for rural food grain demand. The reported income elasticities based on the OLS estimates of the partial adjustment model are from equation (3.16). The income elasticity estimates from the time-varying parameter model are estimated from model defined by equation (4.4) and equation (4.5). Two cases are estimated. The first assumes that the matrix F in state equation follows a random walk, which is F=1; the other assumes that matrix F in the state equation exhibits first order autocorrelation.

Figure 4-1 Rural Food Grain Consumption: CUSUMSQ Test and Recursive Residues

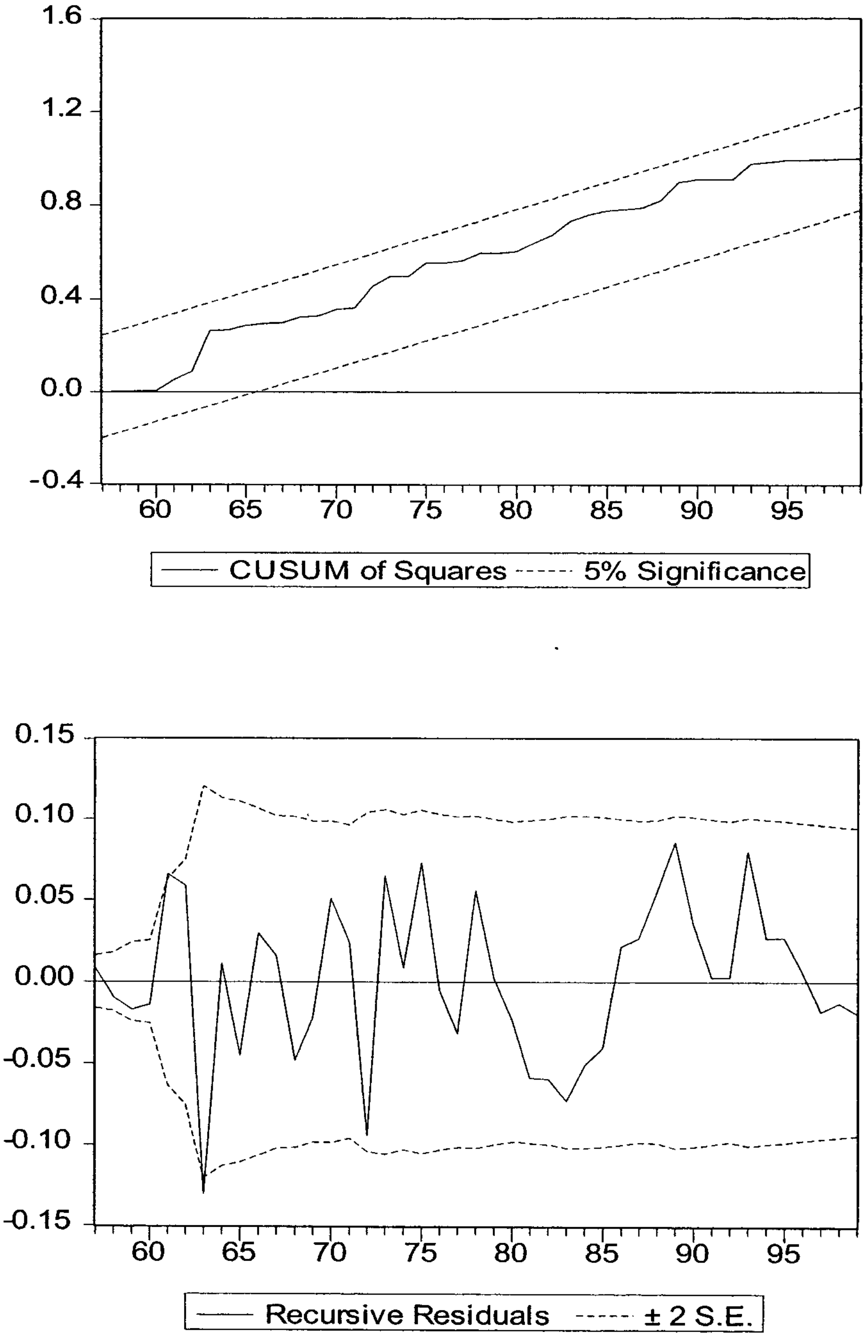
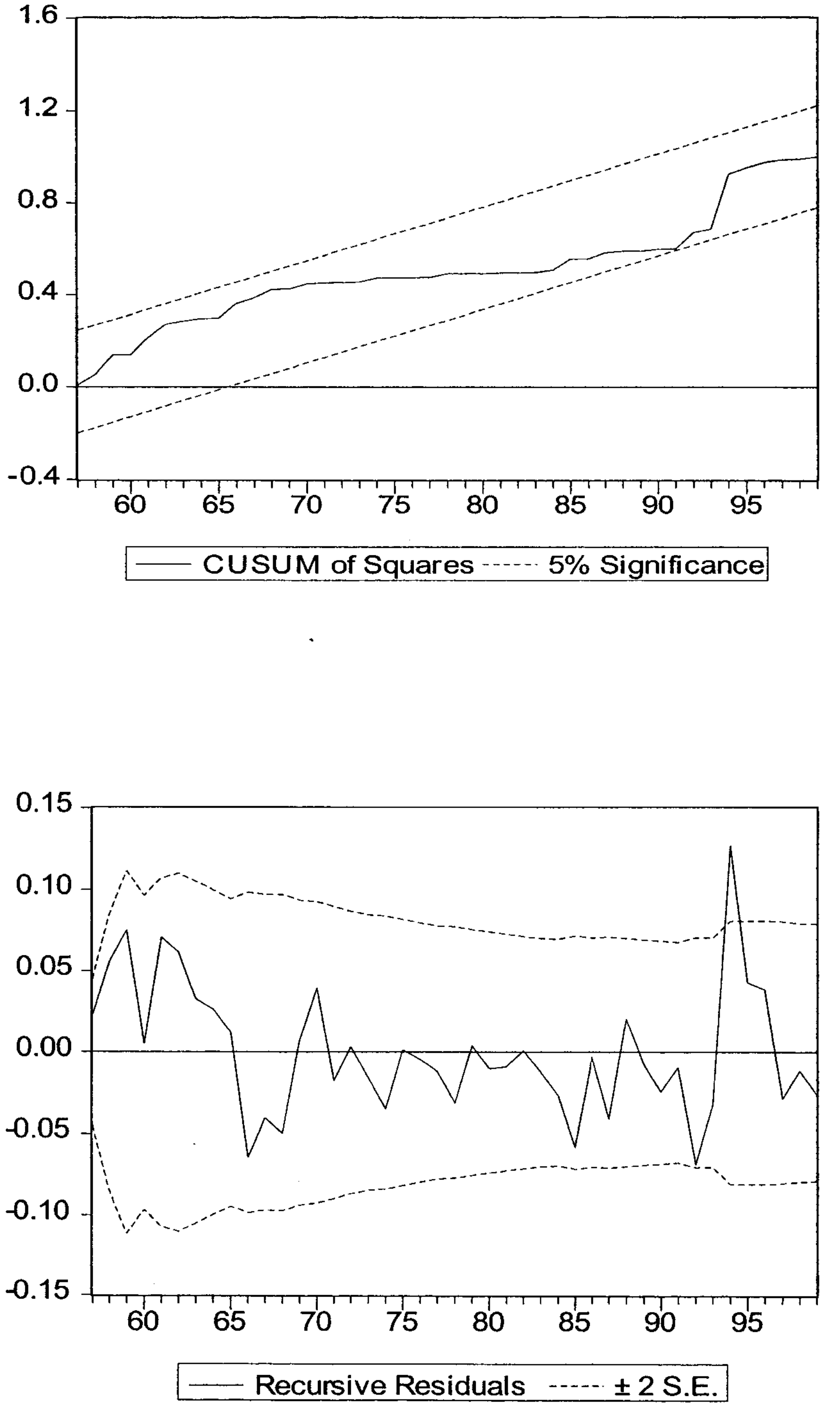
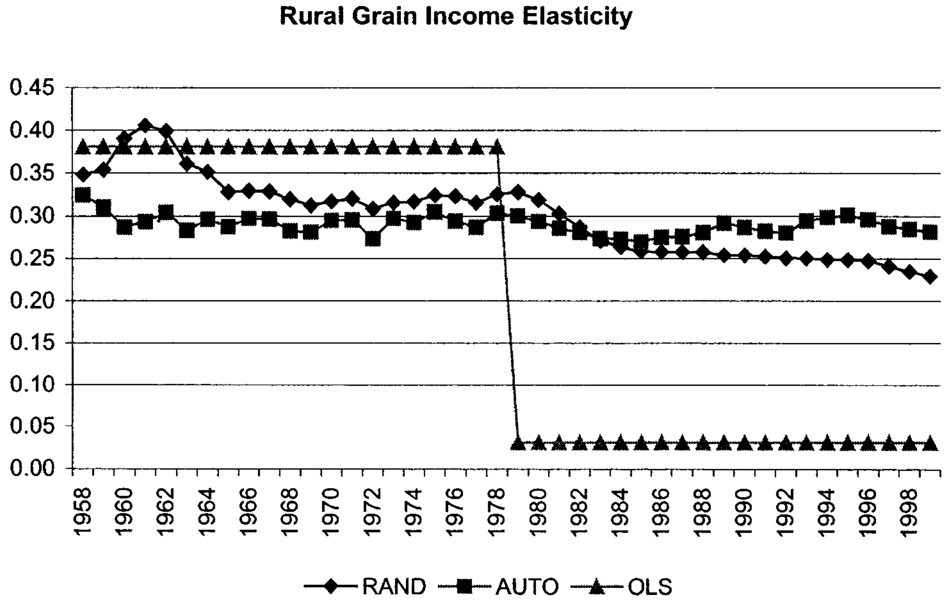


Figure 4-2 Urban Food Grain Consumption: CUSUMSQ Test and Recursive Residuals



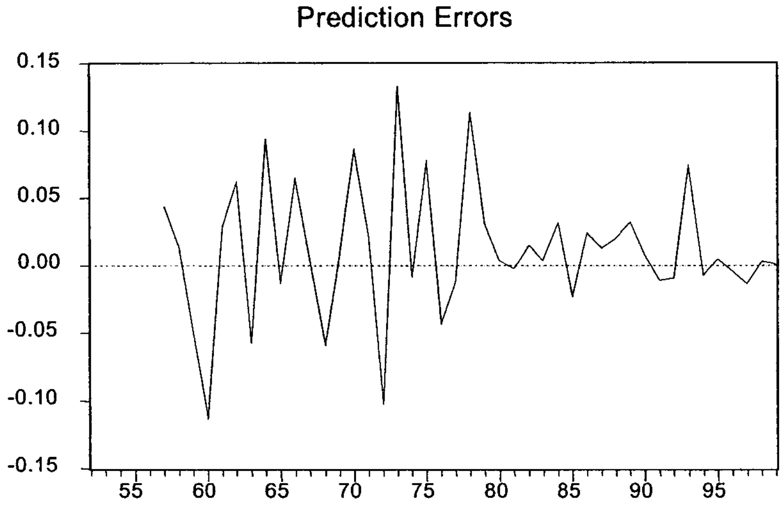
The plots show an abrupt change in the OLS estimates based on the 1978 dummy variable, which indicates the HRS policy change, involving a fall in the income elasticity estimate after 1978. However, as mentioned in section 4.2.1, the change in consumption pattern is less abrupt and does not reflect evolution in the policy and its effects.

Figure 4-3 Income Elasticities for Rural Grain Demand Model, Estimated by Kalman Filtering and OLS; the model obtain ξ_0 by OLS estimation; If *F=I*, the transition equation follows a random walk (RAND case); If F<I, the transition equations assumes AR(1) (AUTO case).



In a well-specified model, the residuals should be approximately random (Harvey, 1990). Diagnostic tests for residuals, such as tests for autocorrelation and for normality, can also be used to test time-varying parameter models. The random distribution of predicted residuals was checked by graphical procedures. For example, Figure 4-4 provides a plot of the prediction errors of rural grain demand estimated by time-varying parameter model about the zero line. The predicted errors do not show an obvious pattern, apart from becoming smaller with time indicating that the model fits the data and the estimation system is stable.

Figure 4-4 Rural Grain Demand: Prediction Errors



Comparing the time-varying parameter model with the constant parameter, partial adjustment model, the former provides more information. The estimated state variables, ξ_t (Equation 4.5) indicate how the elasticities have changed over the years. Thus, the time-varying parameter analysis yields estimates of both price and income elasticities as well as the income elasticity estimates for each year. In the following section, validation of the time-varying parameter models and the partial adjustment models is undertaken to test which model can better predict the various components of grain consumption.

4.3 Validation of the Time-Varying Parameter Model

4.3.1 Forecast Methods

The main objective of this study is to forecast China's future grain demand. Several studies support the general superiority of time-varying parameter over fixed-coefficient methods in forecasting (Conway et al, 1987; Harvey 1990).

The exact finite sample s-period-ahead forecasts of time-varying parameter model can be calculated using the Kalman filter algorithm. The state equation (4.5) can be solved by recursive substitution to yield:

$$\xi_{t+s} = F^s\xi_t + F^{s-1}v_{t+1} + F^{s-2}v_{t+s} + \ldots + F^1 v_{t+s-1} + v_{t+s} \qquad for \quad s = 1, \quad 2..... \tag{4.13}$$

The projection of ξ_{t+s} on ξ_t and Y_t is given by:

$$\hat{E}(\xi_{t+s}|\xi_t, Y_t) = F^s\xi_t. \tag{4.14}$$

Following Hamilton (1994) from the law of iterated projections,

$$\hat{\xi}_{t+s|t} = \hat{E}(\xi_{t+s} \mid Y_t) = F^s\hat{\xi}_{t|t} \tag{4.15}$$

Thus, from (4.14), the s-period-ahead forecast error for the state vector is

$$\xi_{t+s} - \hat{\xi}_{t+s|t} = F^s(\xi_t - \hat{\xi}_{t|t}) + F^{s-1}v_{t+1} + F^{s-2}v_{t+2} + \ldots + F^1 v_{t+s-1} + v_{t+s} \tag{4.16}$$

If the explanatory variable, x_t in equation (4.3) is deterministic, the dynamics of any exogenous variables can be expressed through ξ_t and the s-period-ahead forecast of y is

$$\hat{y}_{t+s} = \hat{E}(y_{t+s} \mid Y_t) = A'x_{t+s} + H'\hat{\xi}_{t+s|t} \tag{4.17}$$

The forecast error is:

$$\begin{aligned} y_{t+s} - \hat{y}_{t+s|t} &= (A'x_{t+s} + H'\xi_{t+s} + w_{t+s}) - (A'x_{t+s} + H'\hat{\xi}_{t+s|t}) \\ &= H'(\xi_{t+s} - \hat{\xi}_{t+s|t}) + w_{t+s} \end{aligned}$$

with a Mean Squared Error (MSE)

$$E[(y_{t+s} - \hat{y}_{t+s|t})(y_{t+s} - \hat{y}_{t+s|t})'] = H'P_{t+s|t}H + R \tag{4.18}$$

A more detailed explanation of forecasting using the Kalman filter approach is provided by Hamilton (1994, Chapter 13, p. 379).

4.3.2 Forecast Validation

Within sample forecasts, which substitute data from 1953 to1999 into the estimated model to forecast demand, are applied. In addition, out-of-sample forecasts are also tested. These arise from a model version that is estimated based on the sub-sample of data from 1953 to 1994, into which are then substituted data from the rest of the sample (1995 to 1999), in order to predict demand during that period. These procedures are applied to develop predictions from both the time-varying parameter model and the partial adjustment model. The sets of predictions are compared for the two models.

There are many possible validation statistics (Granger and Newbold, 1986). The simplest involves visual comparison from plotting the predicted value and the actual value on the same graph with comparison of how well the predicted value follows the actual. Within sample forecasts based on the partial adjustment model and the time-varying parameter model are compared in this way.

Visual comparison can give a very simple and clear idea of how well the forecasts perform, but this approach is not sufficiently accurate. The root mean squared error (RMSE) is widely used to compare actual and simulated values. The expected squared forecast error is estimated as:

$$D^2{}_N = \frac{1}{N}\sum_{t=1}^{N} e_t^2$$

where

$$e_t = Y_t - \hat{Y}_t, \qquad t = 1,2,\ldots.,N$$

Root mean squared errors (RMSE) are the squared root of the average difference between the forecasted number and the actual value. Thus, the smaller the RMSE, the better the forecast. The RMSE is calculated as:

$$RMSE = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(Y_{t+s} - \hat{Y}_{t+s})^2} \qquad (4.19)$$

The root mean squared error (RMSE) statistics for out-of-sample forecasts are calculated and compared to evaluate the forecasts from each of the partial adjustment and time varying parameter models.

The graphical depictions of within sample prediction values of per capita grain, meat, spirits demand from the time-varying parameter and partial adjustment models are given in Figures 4-5 to 4-10. Predictions are indicated by dotted lines; and the actual levels of the dependent variable are shown by the solid lines. The figures suggest that the time varying parameter model provides better within sample prediction, except in the case of rural meat demand. The RMSE test assesses the two models more accurately.

As outlined above, out-of-sample forecasts for the period from 1995 to 1999 are derived for each of the time-varying parameter and partial adjustment models. The underlying models are re-estimated using data only from 1952 to 1994. These form the basis of the forecasts for the subsequent period of 1995 to 1999. The forecasts are compared, as are the root mean squared error (RMSE) statistics for the out-of-sample forecasts.

Both the partial adjustment and the time-varying parameter model give good prediction results. The results in Table 4-2 show that the time-varying parameter models have smaller root mean square errors in prediction for most of the consumption categories, except for the rural meat consumption prediction. Overall, then, the time-varying parameter model is generally better in prediction than the partial adjustment model.

We can evaluate the superiority of the time varying parameter model by testing whether the differences between the RMSE for the two models are statistically different. Granger and Newbold (1986) suggested that the usual test for zero correlation can be used to test equality of expected squared forecast errors. The test is based on the sample correlation coefficient:

$$r = \frac{\sum_{t=1}^{N}(e_t^{(1)} + e_t^{(2)})(e_t^{(1)} - e_t^{(2)})}{\left[\sum_{t=1}^{N}(e_t^{(1)} + e_t^{(2)})^2 \sum_{t=1}^{N}(e_t^{(1)} - e_t^{(2)})^2]^{1/2}\right]} \tag{4.20}$$

The two expected squared errors will be equal if and only if this pair of error terms is uncorrelated. The estimated correlation coefficients between the two sets of error terms are: 0.90, 0.96, and -0.83 for the models of grain, meat and spirits consumption by rural residents.

Figure 4-5: Actual and Predicted Per Capita Rural Food Grain Consumption: Partial Adjustment Model (PAJ) and Time-varying Parameter Model (TVP)

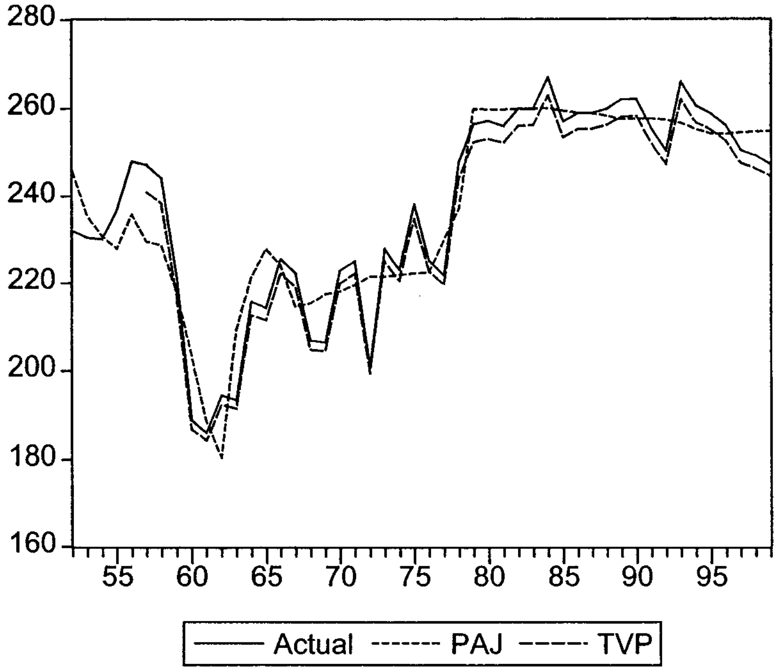


Figure 4-6: Actual and Predicted Per Capita Urban Food Grain Consumption: Partial Adjustment Model (PAJ) and Time-varying Parameter Model (TVP)

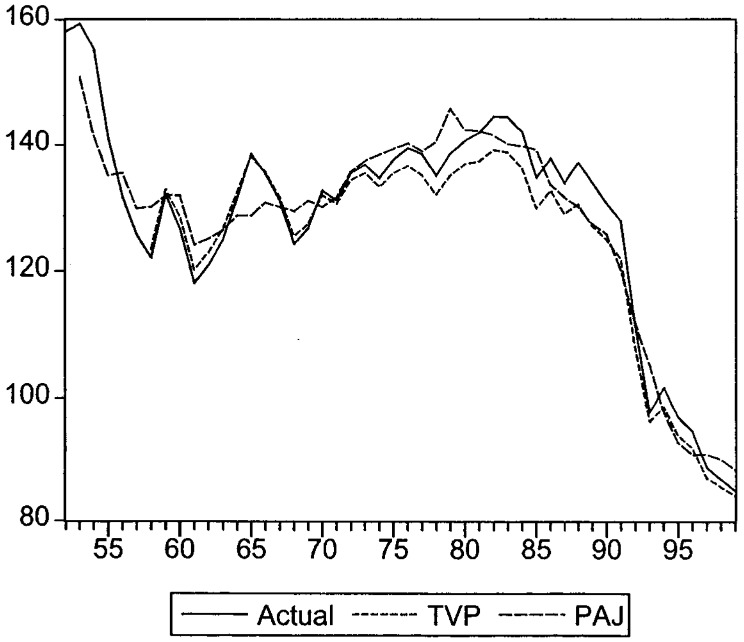


Figure 4-7: Actual and Predicted Per Capita Rural Meat Consumption: Partial Adjusted Model (PAJ) and Time-varying Parameter Model (TVP)

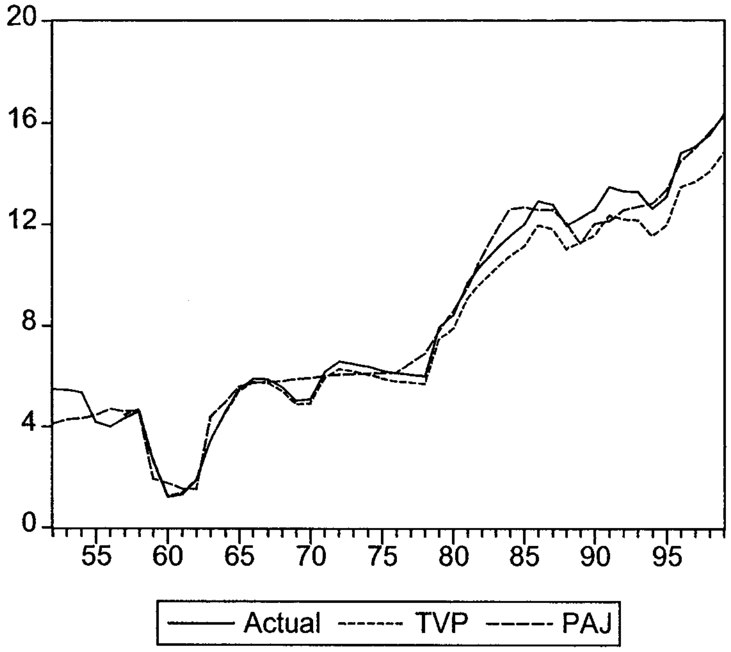


Figure 4-8: Actual and Predicted Per Capita Urban Meat Consumption: Partial Adjustment Model (PAJ) and Time-varying Parameter Model (TVP)

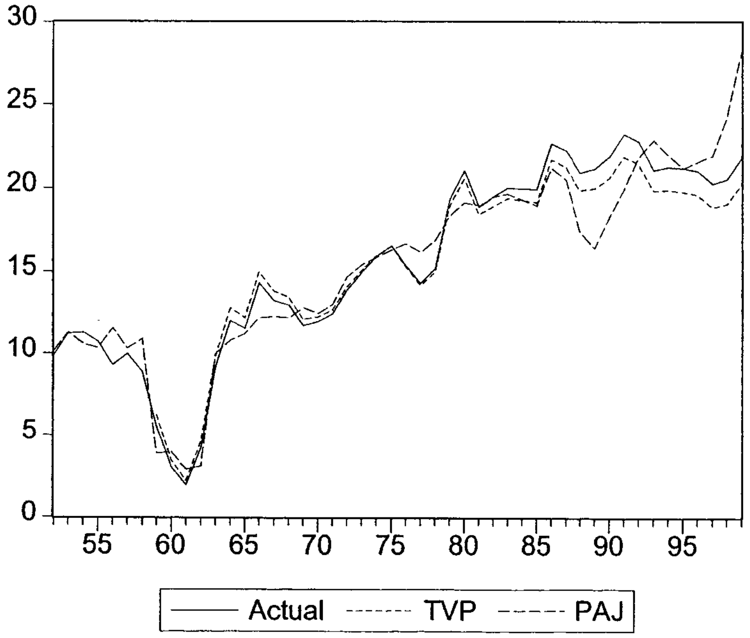


Figure 4-9: Actual and Predicted Per Capita Rural Spirits Consumption: Partial Adjustment Model (PAJ) and Time-varying Parameter Model (TVP)

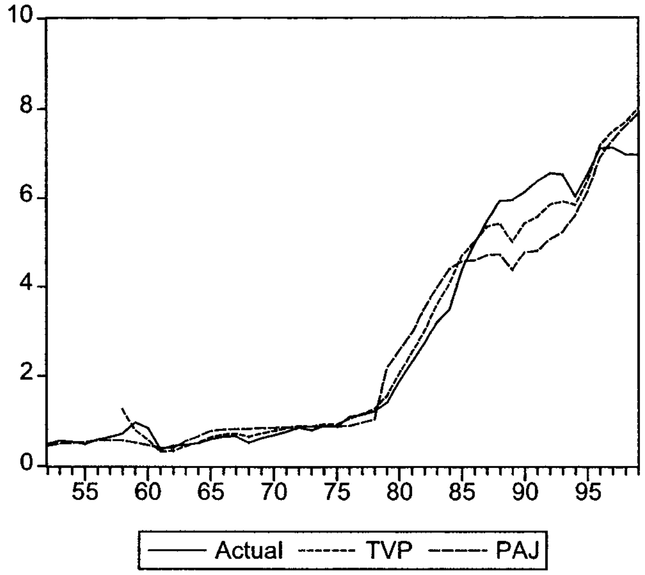


Figure 4-10: Actual and Predicted Per Capita Urban Spirits Consumption: Partial Adjustment Model (PAJ) and Time-varying Parameter Model (TVP)

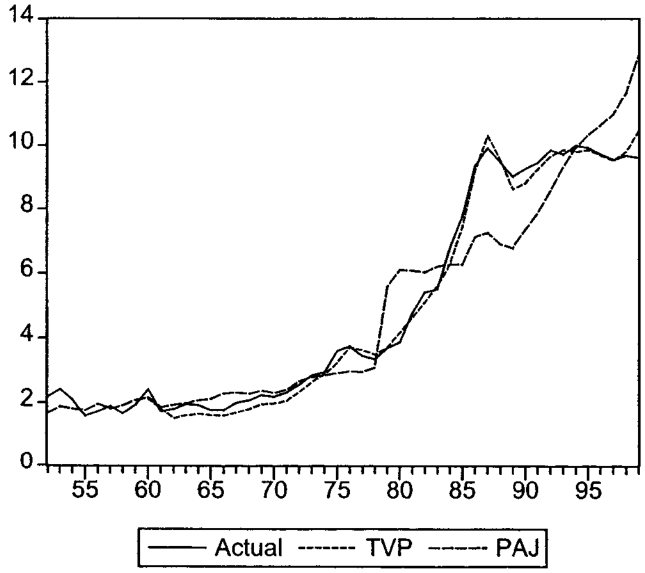


Table 4-2 Out of Sample Forecasts Using Time Varying Parameter Model and Partial Adjustment Model, 1995-1999, Unit: kg/capita

	RURAL			URBAN		
	GRAIN	MEAT	SPIRITS	GRAIN	MEAT	SPIRITS
			Time-varying Parameter Model			
1995	255.21	11.98	6.38	94.07	19.77	9.85
1996	252.74	13.49	7.19	91.84	19.57	9.69
1997	247.66	13.71	7.50	86.91	18.84	9.52
1998	246.42	14.12	7.71	85.41	19.06	9.81
1999	244.76	14.85	8.01	84.12	20.26	10.46
RMSE	3.16	1.36	0.59	2.09	1.48	0.39
			Partial Adjustment Model			
1995	259.31	13.38	4.24	96.04	24.47	12.89
1996	259.91	14.50	4.63	93.97	25.05	13.50
1997	260.42	15.00	4.85	94.80	25.60	14.06
1998	260.72	15.64	5.18	94.66	28.03	15.00
1999	260.99	16.24	5.56	94.23	32.22	16.61
RMSE	9.20	0.20	2.09	6.16	6.62	4.91
			Actual			
1995	258.92	13.12	6.53	97.00	21.21	9.93
1996	256.19	14.83	7.11	94.68	21.04	9.72
1997	250.67	15.08	7.13	88.59	20.28	9.55
1998	249.28	15.53	6.98	86.72	20.53	9.68
1999	247.45	16.35	6.98	84.91	21.83	9.61

For the models of urban residents' consumption, the estimated correlation coefficients are: -0.80, -0.99 and -1.0 for grain, meat and spirits, respectively. The correlation coefficients indicate strong correlations between the two groups of error terms, indicating that the two pairs of expected squared errors, estimated by the partial adjustment model and time varying parameter model, are significantly different from each other. The time-varying parameter model is superior in most cases, except for the estimation of demand for meat by rural residents.

4.4 Summary

A time-varying parameter model using Kalman filter estimation procedure is developed and applied to estimate per capita demand for food grain, meat and spirits consumption in China. In contrast to the approach of fixed parameters and simple inclusion of dummy variables involved in the estimation of the partial adjustment models reported in Chapter 3, the assumption of time-varying parameters seems particularly appropriate for modeling most components of Chinese grain consumption behaviour, apparently because of the nature of the considerable changes in grain policy in China over the period. The model enables the estimation of the time varying path of the income and price elasticities for urban and rural residents.

Predictions from the time-varying parameter model and the partial adjustment model are estimated and compared. The root mean squared errors of predictions from the time-varying parameter models are generally less than for those of the partial adjustment model, suggesting that time-varying parameter models are superior in forecasting.

CHAPTER 5 MEAT PRODUCTION PATTERNS AND THE IMPLICATIONS FOR GRAIN SELF-SUFFICIENCY

5.1 Introduction

A challenging policy objective for the Government of China is to meet the demand for increasing food consumption, while trying to maintain grain self-sufficiency to the extent that is possible, without violating China's World Trade Organisation (WTO) commitments. Examining the feasibility of these goals of food security and some possible ways of achieving these over the next 20 years is the focus of this chapter.

Before the "open door policy" was accepted in China in the 1980s, the government used direct and indirect planning to balance grain supply and demand. (Lardy, 1983; Carter and Zhong, 1988). On the supply side, procurement orders were intended to guarantee basic grain supplies. On the demand side, consumption rationing applied to urban residents to restrict purchases and consumption at regulated prices. With these controls, China was very stable in terms of basic grains consumption. During the period 1965-1977, per capita grain consumption fluctuated slightly, rising slowly from 173 kilograms per capita to 195 kilograms per capita. On average, annual food grain imports were less than 1.8 million metric tons during this period. During the 1950-1960 time period, China exported 2.8 million metric tons processed grain annually. Since the adoption of Household Responsibility System in 1978 and the open door policy in the early 1980s, the rationing system has been abolished and state procurement has been reduced. Abolishment of the current grain-output based system of agricultural taxation has been proposed within the next five years by the Prime Minister's 2004 government report, (Xin Hua News, 03/05/2004). The rapid increase of demand for grain because of income increase and the abolishment of the rationing quota, led to China becoming one of the world's largest net grain importing countries in the late 1980s.

It has been argued that if the domestic supply of grain is to increase, in effect for China to compete with international suppliers, there would need to be support for domestic production. Alternatively, adjustment of meat consumption behaviour could reduce feed grain consumption. (Dixit and Webb, 1990; Gunasekera et al., 1992). Dixit and Webb (1990) and Gunasekera et al. (1992) concluded that the elimination of policies that tax grain producers and subsidize urban consumption of grains could likely lead to China being self-sufficient in grains. Based on more recent research, Felloni (2003) concludes that the price interventions required to maintain China's desired self-sufficiency ratios are significant, and unlikely to be compatible with WTO accession. These authors also conclude that the extent of productivity improvement needed to achieve grain self-sufficiency is likely beyond the current potential of biotechnology, necessitating more reliance on grain imports.

Some researchers, including Tuan (1987), Chow et al (2001), Dixit and Webb (1992), Simpson and Li (2001), and Tian and Chudleigh (1999) focused on China's meat consumption and the demand for feed grain since grain consumption demand is increasingly expected to be driven by meat consumption/production in the future. This is the focus of this chapter, in which a simulation model is adopted to analyze meat production patterns and the consequent demand for feed grain. An Excel spreadsheet model is developed and used to analyze feed grain demand changes in the context of different assumptions. These lead to estimates of potential import demand for feed grain over the next 20 years. The structure of the simulation model is shown in Figure 5-1.

Annual time series data and identified parameters underlie the simulation model. The model projects total grain demand and feed grain demand using, in part, the database and estimates of grain consumption demand parameters, particularly the time-varying price and income elasticities from Chapter Four. Original projections of grain production are not estimated in this study due to limited resources and the availability of other estimates. The estimations and assumptions of Simpson and Li (2001) are used in the simulation analysis to project grain supply. Import demand levels are taken as a residual, based on analyses of grain demand, and production, for the years 2005, 2010 and 2020 under high, medium and low-estimate scenarios.

5.2 Meat Consumption and Feed-Grain Requirements

As the analysis of Chapter 4 indicated, rapid income growth in China has resulted in rapid increase in meat consumption. Per capita consumption of food grain, red meat, and fishery products for rural and urban residents from 1983 to 2000 are given in Table 5-1.

Figure 5-1: Structure of Simulation Model: China's Future Trade in Feed Grains

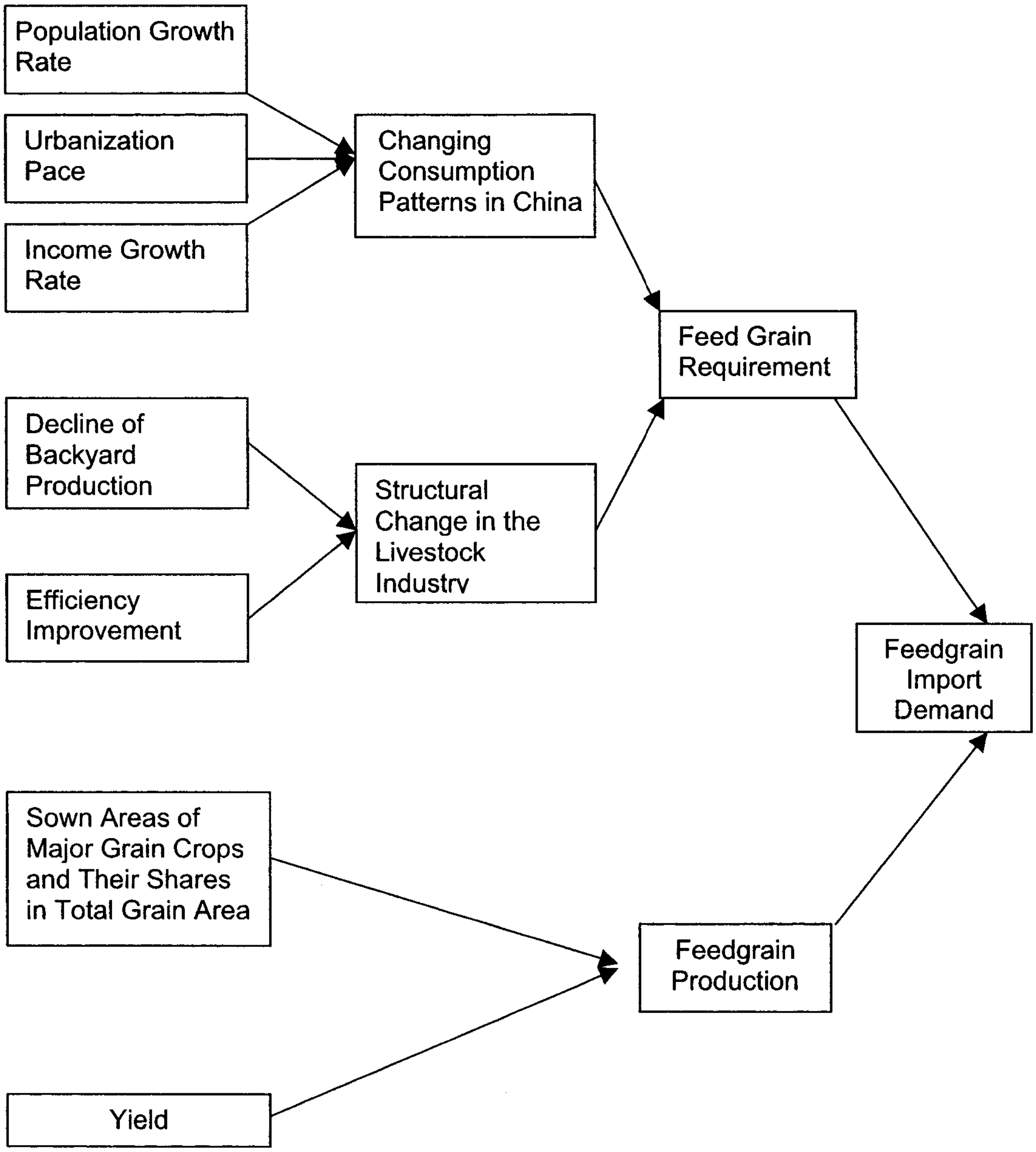


Table 5-1 Per Capita Consumption of Food Grain, Livestock Products, and Fishery Products, 1983-2000, Unit: kilogram

	Food Grain		Red Meat		Poultry Meat		% of	Fishery Products	
Year	Rural	Urban	Rural	Urban	Rural	Urban	Pork[1]	Rural	Urban
1983	260.0	144.5	10.0	19.9	0.8	2.6	84.1%	1.6	8.1
1984	267.0	142.1	10.6	19.9	0.9	2.9	84.0%	1.7	7.8
1985	257.0	134.8	11.0	18.7	1.0	3.2	85.2%	1.6	7.1
1986	259.0	137.9	11.8	21.6	1.1	3.7	84.3%	1.9	8.2
1987	259.0	133.9	11.7	21.9	1.2	3.4	82.3%	2.0	7.9
1988	260.0	137.2	10.7	19.8	1.3	4.0	81.3%	1.9	7.1
1989	262.0	133.9	11.0	20.3	1.3	3.7	80.7%	2.1	7.6
1990	262.1	130.7	11.3	21.7	1.3	3.4	80.2%	2.1	7.7
1991	255.6	127.9	12.2	22.2	1.3	4.4	78.7%	2.2	8.0
1992	250.5	111.5	11.8	21.4	1.5	5.1	76.9%	2.3	8.2
1993	266.0	97.8	11.7	20.8	1.6	3.7	74.4%	2.5	8.0
1994	260.6	101.7	11.0	20.2	1.6	4.1	73.5%	3.0	8.5
1995	258.9	97.0	11.3	19.7	1.8	4.0	69.6%	3.4	9.2
1996	256.2	94.7	11.9	20.4	1.9	5.4	68.7%	3.7	9.3
1997	250.7	88.6	12.7	19.0	2.4	6.5	68.1%	3.4	9.3
1998	249.3	86.7	13.2	19.2	2.2	6.3	68.0%	3.6	9.8
1999	247.5	84.9	13.7	20.0	2.5	4.9	66.9%	3.8	10.3
2000	249.5	82.3	14.6	20.1	2.9	5.4	65.6%	3.9	9.9
Growth Rate	-0.2%	-3.3%	2.3%	0.0%	7.8%	4.4%	-1.5%	5.4%	1.2%

Source: China's Statistical Yearbook, various issues

1. This is the share of pork in total meat consumption, computed from FAOSTAT data.

Table 5-1 demonstrates the declining levels of per capita average food grain consumption for both urban and rural residents. Pork is the major meat consumed, but as Table 5-1 shows, the share of pork in total consumption tended to fall, while consumption of poultry and fishery products grew from relatively small levels over the period from 1983 to 2000. Rural residents' meat consumption grew at a faster rate than was the case for urban residents during this period.

5.2.1 Changing Consumption Patterns in China

Population growth, rate of urbanization and income growth are the factors changing food consumption patterns in China (Rempel, 2002, Huang and Bouis, 2001). The assumptions of these factors are as follows.

Population Growth: The difference in the population growth assumptions of previous studies is small among the reviewed projection models (Huang and Rozelle 1999; Fan et al (1) 1997; USDA 1997). The assumed population growth rate of the above authors is typically close to 1 per cent per year. Some researchers have assumed that the annual population growth rate would decline to 0.74 in 2000-2010 and 0.65 in 2010-2020 (e.g. Fan et al. 1997, p 175). The total population is estimated at 1.27 billion in 2001 and 1.14 billion in 1990 (SSB, 2002). The annual population growth rate was 1.08 percent in 1990-2000. According to the current one child population policy, the rate of population increase will continue to fall. Consequently, an assumption of rate of increase in population numbers of 1 per cent per year is applied in the simulation model.

Rate of Urbanisation: The extent of urbanisation is described by the urban: rural population ratio. Carter and Zhong (1991) assumed the urban: rural population ratio would be 40/60 in 1995-2000. Huang and Rozelle (1999) assume an urban: rural population ratio of 34/66 for 1990-2000, 42/58 for 2000-2010 and 50/50 for 2010-2020. The reported actual urban: rural population ratio was 26.4/73.6 in 1990 and 36/64 in 2000 (SSB, 2001), similar to the assumption of Huang and Rozelle (1999). The urban/rural population ratio assumed in the current simulation model is 45/55 for the period from 2000 to 2010 and 50/50 for the period 2010 to 2020.

Income Growth: The model incorporates the rate of growth in per capita real income in China. A growth rate for average per capita income of 3% and 3.5% for the rural and urban sectors, respectively, was assumed by Huang and Rozelle (1991). Based on data calculations for the late 1980s and early 1990s from China's Statistical Year Book, actual income growth rates were substantially higher in the urban economy (6%-7%) and significantly lower in rural areas (less than 1% per year between 1985 and 1992). However, per capita income growth in the urban area has since slowed and from 1991 to 1999, the rural economy grew at 4% per year (Huang and Rozelle,1999). From ARIMA modeling, based on price and income data from 1952 to 1999, the estimated future per capita income growth rate is projected to be 3.53% in urban areas, with a high of 5% and low of 2%. The possible future per capita income growth rate in rural areas is assumed to be 3.29%, with a high of 4% and low of 1%.

5.2.2 Structural Change in the Livestock Industry

Some 50 % of the world's pigs are raised in China (Table 5-2). As a consequence, China produces almost half of the world's pork (Table 5-3), a reflection of the feature that pork is the major item of Chinese meat consumption (Table 5-1). In 2003, 470 million head of pigs were reported in China. From the population numbers for rural residents, and assuming the average rural family has four members (China's Statistical Yearbook, various issues), the average rural household raises 1.7 pigs. In terms of the numbers of animals, most feedgrain usage in China is for pig and chicken production. Pig raising practices in China differ from those in western countries, and local practice is important in determining the appropriate grain-meat conversion ratio.

Table 5-2 Yearend Inventories of Pigs, Cattle, Chickens, and Goats and Sheep in Selected Countries, 2003, Units: 1,000 head

Country	China	Canada	Japan	USA	World	China Share
Pigs	470,010	14,726	9,725	59,513	952,900	49%
Cattle	108,252	13,372	4,523	96,106	1,368,055	8%
Chickens	4,117,700	160,000	280,000	1,850,000	16,381,477	25%
Goats and Sheep	316,751	1,006	46	7,550	1,793,105	18%

Source: FAO database: FAOSTAT, 2002

Table 5-3 Pigmeat, Beef and Veal, and Mutton and Lamb Output in Selected Countries, 2003, Units: 1000 metric tons

Country	China	Canada	Japan	USA	World	China Share
Pigmeat	45567	1910	1260	8931	95779	48%
Beef and Veal	5619	1245	505	12226	58742	10%
Poultry Meat	13912	1091	1218	17638	75921	18%
Mutton and Lamb	1695	13	0	92	7734	22%

Source: FAO database: FAOSTAT, 2002

Backyard Production vs. Other Production Modes: Both total grain and feed grain import demand depend on the forces underlying changes in consumption patterns in China, as well as the changes that have been occurring in China's livestock industry and the changes in production in China's feed grain sector (Figure 5-1). In particular, feed grain imports may be sensitive to the assumed emerging relative roles of "backyard production" versus "specialised and commercial production" and changes in the grain-meat conversion ratio.

In China, it is common for traditional backyard producers (with less than five sows per family) to raise hogs for family consumption or as a small sideline of agricultural production. However, there has been a tendency for gradual increases in the size of pork production units. This has included the recent rapid growth in specialized hog production units. The mode of specialized hog production has developed from the practice of traditional backyard production (Tuan, 1987). A typical specialized hog producer had 20 sows in the 1980s but by the 1990s, a typical specialized hog producer had more than 50 sows (Simpson, 1994).

Backyard production had fallen to a historically low share of less than 10% of total output before the 1978 economic reform, due to the policy of collectivisation (Zhou and Tian 2003). The introduction of the household responsibility system (HRS), however, greatly encouraged household production. The share of China's total pork output from backyard production increased sharply then gradually declined from the initial peak following the reform. Specifically, the share of backyard output in total pork production is estimated to have increased to a peak level of 95% in the 1980s and then gradually declined (Tuan, 1987).

Currently, about 75 to 80 percent of China's pork output is believed to come from backyard feeding, 15 percent from specialised households, and 5 to 10 percent from large-scale commercial operations (Tuan et al 2001). Following economic reform the number of backyard producers of hogs increased rapidly and then fell. The decline was related to rapid economic growth in China, which led to increased employment opportunities in non-agricultural sectors (Zhou and Tian, 2003). As a result, many families that had previously raised pigs as a complementary sideline operation ceased production. Simultaneously, the size and number of individual operations grew. According to Simpson's survey in 1994 (Simpson et al. 1994), a typical household had 2 sows in 1991 (compared with 1 in 1986).

With growth in the market economy, large structural changes are expected in Chinese hog production. Simpson et al. (1994) noted that these seem to be following the patterns of structural changes that have taken place in Canada and the United States in earlier years. For example, between 1981 and 1991 there was a decline in the number of pig farms in the United States by approximately 56 percent and from 1971 to 1981 there was a further decline in pig farm numbers, by roughly 33 percent (Simpson et al. 1994).

The structural changes occurring in China's hog production technologies have been associated with improved feed efficiency and significant output increases. Assume that the output of specialised households' hog production will increase to 20 percent of total output, that large-scale commercial operations will account for 10 percent of total output by 2010, and that large-scale commercial operations and specialised operations will account for 40 percent of total meat output in 2020.

Technical Feed Requirements of Different Production Modes: Feed intake differs in the different production modes, such as backyard production, specialized production and commercial or state production modes. The types of production described as backyard, specialised and commercial operations are quite different. Following Simpson et al. (1994), the parameters of these three production practices are listed in Table 5-4.

Table 5-4: Production Parameters, Suburban Hog Finishing Operations of Backyard, Specialised and State Production Mode in 1991

Item	Units	Backyard	Specialised	State
Number of Sows	Head	10	50	1000
Initial age	Days	90	60	55
Fattening period	Days	180	150	135
Age at slaughter	Days	270	210	190
Weight at slaughter	Kg	100	100	90
Average daily gain	Kg	0.49	0.49	0.57
Death loss	Pct	2	3	3

Source: Fieldwork by Simpson, et al (1994)

There is a lack of information on feeding practices in the backyard production mode and the precise use of non-conventional feed resources (NCFR), which includes by-products and various waste products in total livestock feed. Different authors have used different estimates of grain-meat conversion ratios in undertaking feed grain demand projections.

The range of these estimates is illustrated by Zhou and Tian (2003). Their tabulation of the grain-meat conversion ratios for pork used in different reports by different economists and in Chinese government reports indicate that these have varied from a maximum of 8 to a minimum of 3.1; the grain-meat conversion ratios for poultry have varied from a maximum of 5 to a minimum of 1.9; and the one with largest difference is beef, ranged from a maximum of 10 to a minimum of 2. The range of grain-meat conversion ratios is listed in Table 5-5.

Table 5-5 Summary of Grain-meat Conversion Ratios Used in Chinese Feedgrain Demand Research

Author	Pork	Beef	Mutton	Poultry	Eggs	Milk	Fish
Liu et al (1988)	8	10		5	5		
MOA (1988)[1]	5.8			3	3-3.5	1	1.5
Zeng (1988)	4.5			2.2	3.2	0.4	1.5
Carter et al (1988)	4			4			
Lu (1989)[2]	4			2.5	2.5-3		
	5-6			3.5	3-3.5		
Gao (1990)[1]	6-7	3.3		2			1.5
Yu(1991)[1]	5.1	3		3	2.8-3	0.33	2
Food Study Group (1991)[1]	5.5-6.4	4.8		2.5-3.8	3-3.5	3	
Editing Committee of MOA (1991)[1]	4-4.5	2		2.5			2
Zhou (1993)	5			2.2	2.8		
RGCFDS (1993)	5.5-6			2.5-3.5	3-3.5		
Wang and Huo (1996)[2]	3.1			1.9	2.7		
	3.2			2.2	3		
Cheng et al (1997)	3.5	3.2	3.2	2.1	3	1.84	
USDA (1997)	3.5			2.1			
NORHS (1998)[3]	3.3-3.5						
	3.24	2	1.13	2.36	2.96		
	3.47	4.01	1.34				
Guo, et al. (2001, p. 23)	4	4	4	4	2.5	0.3	0.8
Minimum	3.1	2	1.13	1.9	2.5	0.3	1.5
Maximum	8	10	4	5	5	3	2
Average	4.7	4.03	2.42	2.79	3.13	1.15	1.55

Source: Zhou and Tian (2003, page 16, Table 4)

1. Garnaut and Ma (1992, p.76).
2. Row 1: more efficient feeding practices; Row 2: on average.
3. Row 1: for feedlots; Row 2: specialised households; Row 3: backyard raising.

Changes over time in animal breeding or management that result in higher feed efficiency and a lower grain-meat conversion ratio can be expected to occur over time in China and anticipations of such changes have been projected by some analysts. Tuan (1987) projected that the pork grain-meat conversion ratio would decrease from 4.0 in 1983 to 3.88 in 2000. The poultry grain-meat conversion ratio was also projected to decrease, from 3.2 in 1983 to 2.81 by 2000 (Tuan, 1987). However, these conversion ratios, which are relatively close to western levels or typical of larger-scale production (annual output greater than 1000 kilograms), may not be applicable to the production technology of backyard production since this includes substantial use of non-grain feeds.

To project feed grain demand, an appropriate grain-meat conversion ratio should be applied. This should exclude non-grain feed and thus reflect actual grain consumption and demand. To develop an appropriate grain-meat conversion ratio, the composition of feed should be considered.

Table 5-6 shows that the biggest difference between the mode of backyard production and that of specialised households is that the proportion of compound feed in total feed in specialised production units (24.5%) is much higher than that in backyard production (<10%). The compound feed usage in specialised production units is almost three times more than compound feed use in backyard production units. On the other hand, the use of Non Conventional Feed Resources in backyard production, the sum of the first two lines in Table 5-6, is much higher than the use of Non Conventional Feed Resources in the specialised production mode, being 49% and 30%, respectively, for the backyard production and specialised production modes. The share of unprocessed grain in the feeding diet in the various backyard feeding operations seemed quite high, particularly for the smallest operations from the survey of Simpson et al. It should be also noted that feed composition patterns vary greatly among regions (Zhou and Tian, 2003).

Table 5-6: Characteristics of Specialised Household and Backyard Pork Operations, by Size, China

Item	Backyard feeding operation by annual output**			Specialised households
	<200kg	200-500kg	>500kg	
	Percent of feed by weight			
Feed ingredients				
Green feed + waste products (dry weight)	18.9	18.0	21.7	12.9
Bran (wheat, rice)	37.1	30.8	20.3	17.4
Oilseed meals	0.8	1.2	1.8	4.2
Unprocessed grain	39.9	42.6	46.3	38.3
Compound feed	3.0	6.8	8.6	24.5
Premixed additives	0.3	0.5	1.2	2.7
Total	100.0	100.0	100.0	100.0

** Live weight of hogs

Source: Government of China, Ministry of Agriculture Livestock Survey (1997).

Pig production in coastal areas was limited by the availability of non-conventional feed resources (NCFR) and faced rapidly rising opportunity costs of labour in the 1990s. Coastal areas generally had higher grain-meat conversion ratios than inland areas (Zhou and Tian, 2003). However, the anticipated surge in commercial hog production and the consequent expected use of feedgrains were considerably dampened in coastal areas due to increased competition from small producers, using backyard production modes, in inland areas of China. This resulted, in part, from the development of modern freeway and highway systems, which reduced the cost of transport of slaughter hogs and meat from inland to coastal areas. As a consequence, the evolution of structural change in China's hog feeding proceeded more slowly and the need for feedgrains rose more slowly than originally expected. However, the limited information on these changes adds to the difficulty of the derivation of national averages of feed composition by production modes.

Among backyard production operators, with the increase of non-farm opportunities, the opportunity cost of raising pigs is steadily increasing. If only one or two pigs are raised, it is not very profitable. A survey by Zhou, Tian and Liu in 2000 showed that more farmers are raising hogs to increase family income instead of home consumption and that they intend to raise the production number and become a specialised household (Zhou and Tian, 2003, p87). There is also evidence from Table 5-6 that feed grain usage in backyard production differs according to the size of operations. Feed usage of NCFR and additives in operations with annual output more than 500 kilograms are different from feed use in operations with annual output less than 500 kilograms. One pig usually weighs 100 kilograms (Table 5-4), so the output of 500 kilograms is roughly the output of 5 sows. We refer to operations with 5 sows or less annually "typical backyard production" and those with 5 or more sows as "improved operations", following Simpson et al. 1994.

In the typical backyard mode of production, pigs are fed on non-grain feeds, mainly table scraps or greens, and there is little if any use of grain, additives or concentrates. This is a low scale and low cost mode of production.

Thus in the 1980s, finished hogs in the mountain areas of China averaged 420 days of age at slaughter, while hogs shipped from suburban State Farms were slaughtered at half that age, at about 210 days (Table 5-4). Simpson et al. (1994) argues that non-grain feed use in backyard production, including feeding of non-conventional foodstuffs such as water plants and use of forages for pasture-based operations, can be expected to continue to be a significant component of China's swine industry for years to come (Simpson, 1994, p70). Grain use is likely a small component of the improved typical backyard production. Hogs produced in this way are not routinely sold for commercial purposes, since this represents a sideline production practice for farmers to improve their livelihoods, although sometimes farmers sell pigs to increase the family income.

The improved backyard production mode is still a backyard style of production, but these farmers tend to use relatively more grain and more compound feed and additives in their production operations. The information collected by the MOA survey (Table 5-6) will be used to adjust the prevailing grain conversion ratio for the improved backyard production mode. For the typical backyard production mode and specialised production mode, we will use survey results by Simpson et al. (1994) and other information.

According to the field survey by Simpson et al. (1994), the grain-meat conversion ratio for improved small and large hog production unit is 3.3, which includes specialised households that typically have more than 50 sows. Grain-meat conversion ratios in developing countries are reported to be 1.8 for pork and 1.6 for poultry meat and eggs (Medrano 1999). Because of the paucity of information on the grain-meat conversion ratio for typical backyard production in China, Medrano's figure of 1.8 for pork and 1.6 for poultry production is used in our simulation model.

Grain accounts for 70% of compound feeds and 30% of green and waste products, which are grain by-products (Tuan, et al; USDA/ERS, 2000). Consequently, the total grain used as feed for the improved backyard production can be calculated by the formula:

Total grain = unprocessed grain + 0.7 * compound feed+0.3*waste products.

Thus, the adjusted grain-meat conversion ratio will be:

Adjusted grain/meat conversion ratio = grain/meat conversion ratio*
(percentage of unprocessed grain (46%)
+ 0.7*percentage of compound feed (9%)
+0.3*waste products (40%)) (4-1)

To derive a grain-meat conversion ratio for the improved backyard production mode, we take an average pork grain-meat conversion ratio of 4 and apply the percentage of unprocessed grain, compound feed and waste products for the average feed composition of backyard production, listed in Table 5-6, to arrive an adjusted grain-meat conversion ratio for the improved backyard production mode. The grain-meat conversion ratios for typical production, improved backyard production and the state/specialised production modes that we adopt are shown in Table 5-7.

Table 5-7 Adjusted Grain-meat Conversion Ratios of Pork, Poultry and Egg Production for Different Production Modes

Item	Pork	Poultry	Egg
		Ratios	
Typical Backyard[1]	1.80	1.60	1.60
Improved Backyard[2]	2.57	2.08	2.08
State/ Specialised[3]	3.30	3.11	3.11

Sources: 1. Medrano and Bradford (1999); 2. Calculated by author; 3. Simpson (1994)

In terms of the various production technologies, we assume that 25% of production is from typical backyard production units, whose annual output is each less than 500 kilograms, whereas 50% is assumed to be from improved backyard production modes, from units for which annual output is more than 500 kilograms.

As production efficiency improves, the grain-meat conversion ratio can be expected to decline; with future expected increases in the share of specialised firms in the production of hogs, feed grain usage will increase. The grain-meat conversion ratio will change according to the influence of these two features. It can be expected that the grain-meat conversion ratio for different production modes will, in the very long term, converge to the ratio that applies in western countries, 3.7 for example, which is the figure applicable for pork production in developed western countries. Nonetheless this type of change is not expected over the next 20 years and in the simulation, the grain-meat conversion ratios are assumed to be constant at current levels shown in Table 5-7 for the next 20 years. The key assumptions that underlie the simulation scenarios for feedgrain requirements are summarized in Table 5-8.

Table 5-8 Summary of Key Assumptions in the Simulation of Feed Grain Requirements in China

	Annual Growth Rate (%) or accordingly		
Factors	Low	Baseline	High
Total Population:			
2000-2010	0.7	1.0	1.10
2010-2020	0.7	1.0	1.10
Rural/Urban:			
2000-2010	60/40	55/45	50/50
2010-2020	55/45	50/50	45/55
Per capita real income			
Rural	1.0	3.29	4.0
Urban	2.0	3.53	5.0
Share of backyard production			
2000-2010	75%	70%	65%
2010-2020	65%	60%	55%
Grain meat conversion ratio	Typical backyard	Improved backyard	State /specialised
Pork	1.8	2.57	3.70
Egg/Poultry	1.6	2.08	3.11

Restaurant Consumption: Away from home consumption of food is an important component of urban food consumption. Grain consumed in restaurants is estimated to account for 10% of total urban food grain per capita consumption while meat consumed in restaurants accounts more than 10% of urban meat per capita consumption (USDA/ERS, 2003). Assume that out-of-home consumption of directly consumed grain and indirect grain consumption (such as meat and spirits consumption) accounts for 10% of total urban consumption of grain in the next 20 years.

5.3 Total Grain and Feed Grain Production

Fan et al (1997), Huang and Rozelle (1999), and Simpson and Li (2001) have projected grain production for the year 2020. The projection by Simpson and Li is based on China's revised census data on cultivated areas that was published in 1997.

Compared with some other projections of crop production (Table 2-4), the projection by Simpson and Li is higher than for numbers of other studies, including those by USDA/ERS (1997), Huang and Rozelle (1999), Fan et al (1997(1)) and IFPRI (1997). The optimistic production projections by Simpson and Li stem from assumed yield increases due to the adoption of new technology in agricultural production and the lower downward adjustment of farmland area. From the range of supply projections, we apply the projections by Fan et al, Huang and Rozelle and Simpson and Li as the basis, respectively, of the low, medium and high projections for crop production in the simulation analysis reported in this chapter. Since the projection of Simpson and Li is based on the Chinese State Statistical Bureau (SSB) database, the grain definition is different than that used by USDA. Following the procedure outlined in Chapter 2, estimation results based on the SSB database will be adjusted by a rate of 0.85. The projections by Fan, et al, Huang et al and Simpson et al are listed in Table 5-9.

Simulated grain import demand is projected as the residual difference between feed grain production and consumption. We develop and test a simple simulation model of prospective grain imports based on the following key assumptions and parameters.

Table 5-9 Production Projections by Fan, Huang and Simpson for 2005-2020, Units: million metric tons

Year	Fan et al, (1997(1))	Huang et al, (1999)	Simpson et al, (2001)
Avg. 90-95	362	362	362
2005	*399*	*392*	417
2010	417	421	480
2020	449	491	498

Sources: Fan et al (1997(1)); Huang and Rozelle (1999); Simpson and Li (2001).

5.4 Baseline Projection of Demand

5.4.1 Projection of Per Capita Grain and Feed Consumption Demand

Total domestic demand for grain includes the uses of human consumption, seed requirements, industrial uses and reserve stock requirements. Per capita consumption demand models were estimated for both urban and rural residents in Chapters 3 and 4. To project the quantities of future human consumption, appropriate rates of growth in personal income and related prices must be identified and employed.

Domestic price changes are correlated with world price changes, so the price changes from USDA's baseline projection (USDA 2002) are used as the basis to estimate future changes in China's grain, meat and spirit price levels. On this basis the annual rate of increase in prices of grain, meat and spirits are assumed to be 0.6%, 0.63% and 1.61% respectively[8]. Grain prices are expected

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[8] Source: USDA (2002) baseline projection. The USDA projections of rates of growth in prices for wheat, pork and barley are taken as prices for the rates of growth in prices of grain, meat and spirits, respectively.

to be more influenced by the international market than in previous years due to China's accession to the World Trade Organization.

Table 5-10, Forecast of Grain, Meat and Spirits Prices and Real Per Capita Incomes in 2000 to 2030

	Urban (1952=100)				Rural (1952=100)			
Year	Grain	Meat	Spirit	Income	Grain	Meat	Spirit	Income
2000	992.50	1073.94	367.28	884.04	1294.88	1593.83	316.53	570.26
2010	1022.64	1108.20	397.81	1051.49	1334.20	1644.67	342.84	670.45
2015	1053.69	1143.55	430.88	1250.65	1374.70	1697.13	371.34	788.24
2020	1118.64	1217.67	505.50	1769.28	1459.45	1807.14	435.65	1089.54
2030	1187.60	1296.60	593.05	2502.99	1558.72	1924.27	511.10	1506.00
a. g. r.[1]	0.60%	0.63%	1.61%	3.53%	0.60%	0.63%	1.61%	3.29%
High	1.0%	1.0%	2.0%	5.00%	1.0%	1.0%	2.0%	4.00%
Low	0%	0.5%	1.0%	2.00%	0%	0.5%	1.0%	1.00%

[1] a.g.r denotes annual growth rate. Source: Computed by author.

Per capita grain consumption for the next 30 years is predicted from the time-varying parameter models, discussed in Chapter 4, in which the price and income elasticities are the time varying parameters and the state variables are recursively estimated following an AR(1) process. The predicted levels of per capita food grain, meat and spirits demand are given in Table 5-11.

The estimates from the time-varying parameter models are that food grain consumption by urban and rural residents will decrease at annual rates of 0.57 percent and 0.07 percent respectively from 2000 to 2030. Meat consumption by urban and rural residents is projected to increase by approximately 3.17 and 3.21 percent annually, respectively. Urban and rural residents' spirits consumption is projected to increase at 2.04 percent and 3.8 percent respectively. Overall, then, for both rural and urban residents per capita direct food grain consumption is projected to decrease, while per capita spirits and meat consumption will increase.

Table 5-11 Projected Per Capita Food Grain, Meat and Spirits Demand for Urban and Rural Residents in 2005 to 2030

	Urban (kg/capita)			Rural (kg/capita)		
YEAR	Food Grain	Meat	Spirits	Food Grain	Meat	Spirit
2005	82.03	26.15	10.83	239.75	18.39	11.20
2010	78.84	30.40	11.96	237.21	21.76	13.49
2015	75.40	35.35	13.21	235.77	25.56	16.22
2020	72.14	41.21	14.72	235.23	29.94	19.68
2025	71.31	47.91	16.26	235.26	34.89	23.66
2030	70.77	55.70	17.96	235.86	40.57	28.45

Source: Computed by author

Even though meat consumption is projected to increase rapidly, the level of per capita meat consumption projected for 2030 is still much lower than currently in developed countries. For example, per capita red meat and poultry consumption in the U.S. in 1999 was 84 kilograms (FAO, 2002). The projected average meat consumption level of urban resident in 2030 is 55.7 kg, which is 65% of the 1999 U.S. meat consumption level.

The level of per capita pork and poultry consumption for China from 2005 to 2020 is projected to increase at an annual rate of 2.9% and 3.6% respectively for urban residents. Per capita pork consumption is projected to increase from the level of 17 kilograms per capita in 2000, to 30 kilograms per capita in 2020 for urban households. Per capita poultry consumption will increase from the 2000 level of 5 kilogram per capita to 11 kilograms per capita in 2020 for urban households. The projected per capita pork and poultry consumption of rural households increases at an annual rate of 3.1% and 4.3% respectively from 2005 to 2020. Per capita pork consumption is projected to increase from the current level of 13 kilograms per capita in 2000 to 24 kilograms per capita in 2020 for rural households. Per capita poultry consumption will increase from the current level of 3 kilograms per capita in 2000 to 6 kilograms per capita in 2020 for rural households. Per capita poultry consumption is projected to increase at a faster rate than per capita pork consumption for both urban and rural households in the period from 2005 to 2020. Table 5-12 gives the estimates of per capita consumption of pork, poultry and eggs for rural and urban residents in selected years for the period from 2005 to 2020.

Table 5-12 Projected Per Capita Meat Consumption in Selected Years: 2005-2020

	Rural (kg/capita)			Urban (kg/capita)		
	Pork	Poultry	Egg	Pork	Poultry	Egg
2005	15	3	6	20	6	13
2010	18	4	8	23	8	15
2015	21	5	10	26	9	18
2020	24	6	12	30	11	22

Source: Simulation results

5.4.2 Projection of Total Grain Demand

Total grain demand is calculated as the summation of grain consumption from the projected consumption of total food grain, feed grain and grain used for spirits. For this purpose, conversion from estimates of the processed form of grain should be converted to unprocessed form. In direct food grain consumption, urban food grain statistics are measured in the form of flour, while rural food grain statistics are measured in unprocessed form. Thus, a 0.79 grain milling ratio is applied to urban food grain forecast amounts to transfer grain in flour form to unprocessed grain form. The grain for spirits is estimated by applying a 0.98 spirits to grain ratio. Total quantities demanded of grain are estimated by multiplying the quantities consumed per capita by population levels for the projection years of 2005 to 2020.

Table 5-13 Projected Total Meat by Different Production modes in Selected Years: 2005-2020, Unit: million metric tons (mmt)

	Pig Production				Chicken	Eggs
	Total (mmt)	Typical Backyard	Improved Backyard	Specialized and State		
2005	29	7	14	7	13	26
2010	36	9	17	10	18	35
2015	44	11	20	13	24	47
2020	52	13	21	18	30	60

Source: Simulation results

Projected demand for feed grains is estimated by multiplying the projected consumption levels for pork, poultry and eggs by their respective grain-meat conversion ratios. The estimated projected total meat demand and feed grain demand are shown in Table 5-13 and Table 5-14. Total feed grain consumption is projected to double by 2020, increasing from 99 million metric tons in 2005 to 192 million metric tons in 2020. Feed usage in poultry and egg production is projected to increase to 47 percent of total feed usage.

The medium level predictions for total grain consumption during the next 20 years are shown in Table 5-15, and are the baseline scenarios for total grain consumption projections. According to the baseline scenario, direct human consumption of food grain increases at an annual rate of 0.02%. The consumption of spirits and feed grain is projected to increase relatively rapidly in this scenario. Feed grain demand increases especially quick, about 4.6 percent annually from 2005 to 2020. Total grain demand will increase at an annual rate of 1.7%.

Table 5-14 Projected Total Pork, Poultry and Egg Based Feed Demand Among Urban and Rural Sectors in Selected Years: 2005-2020, Units: million metric tons (mmt)

	Total	Urban			Rural		
	mmt	Pig Feed	Chicken Feed	Egg Feed	Pig Feed	Chicken Feed	Egg Based Feed
2005	99	28	8	16	30	6	11
2010	127	36	11	22	36	7	13
2015	161	48	15	29	42	9	18
2020	192	57	18	36	49	11	22

Source: Simulation results

Table 5-15 Baseline Predictions of Grain Demand, 2005-2020

YEAR	FOOD GRAIN (mmt)	SPIRITS (mmt)	FEED GRAIN (mmt)	Total Demand (mmt)
2005	251	15	99	365
2010	253	18	127	397
2015	256	22	161	439
2020	252	26	192	470
Annual Growth Rate	0.02%	3.7%	4.7%	1.7%

The figures for food grain demand are expressed in unprocessed form. This is calculated by applying the assumed milling rate of 0.79 percent to food grain consumed by urban residents. Similarly, input: output ratios of 0.98:1 are assumed as the spirits to grain ratio.
Source: Computed by author.

5.4.3 Analysis of Sensitivity to Key Assumptions

To test how the projection results change if the key assumptions are changed, sensitivity analysis of the estimation results to key assumptions is carried out, using Excel spreadsheets. Demand projections when one assumption is changed (grey area, as in Table 5-16) while holding other assumptions unchanged, are compared with the original demand projection of the base estimation model.

Sensitivity Analysis of Population Growth Rate and Speed of Urbanization

Demand projections are compared when annual rate of population growth assumptions are changed from the current rate of 1.0 percent to a low of 0.7% and a high of 1.1%, while holding the rest of the assumptions unchanged. If the annual rate of population growth is 1.1% instead of 1% in the years from 2000 to 2020 and other factors are unchanged, the total demand for grain increased by 10 million metric tons in 2020 based on the projection model.

Under the baseline assumption, the share of the population in urban areas is 45% in 2010 and 40% in 2020. We increase the urban population share to 50% in 2010 and to 55% in 2020 in the high urbanization scenario, and also decrease the share of urban population to 40% in 2010 and 45% in 2020 in the low urbanization scenario, to assess the effects of different rates of urbanization on grain demand. The simulation results show that an increase in the rate of urbanization does not appreciably increase total grain demand. This may reflect the influence of a larger urban population on increases in the demand for fine grains, offsetting changes in the share of animal products in the everyday diet.

Coarse grains are substituted by fine grains in people's diet with increasing income associated with urbanisation. The release of coarse grain from people's diet because of this substitution may have outweighed the demand for feed grain (Dong et al, 1995). Therefore, total grain demand does not increase, but instead decreases. Table 5-16 indicates the variations in annual population and urbanization growth relative to total grain demand.

Table 5-16 Analysis of Sensitivity in Total Grain Demand to Variations in Annual Population and Urbanization Growth

Scenario Summary		Base Estimation	(1) Low Rate of Pop Increase	(2) High Rate of Pop Increase	(3) High Rate of Urbanization	(4) Low Rate of Urbanization
Changing Cells:						
00-10	Pop	1.0%	0.7%	1.1%	1.0%	1.0%
10-20	Pop	1.0%	0.7%	1.1%	1.0%	1.0%
00-10	Urban Pop Share	45.0%	45.0%	45.0%	50.0%	40.0%
00-10	Urban Pop Share	50.0%	50.0%	50.0%	55.0%	45.0%
Result Cells:						
2005	TOTAL	365	359	367	360	369
2010		397	386	401	391	404
2015		439	420	446	433	446
2020		470	443	480	439	503
2005	TL Food	251	248	252	246	256
2010		253	245	255	244	261
2015		256	245	260	246	265
2020		252	237	257	232	272
2005	TL Feed	99	97	99	94	93
2010		127	123	128	124	118
2015		161	154	163	158	151
2020		192	181	196	177	197

Notes: Base Estimation column represents values of changing cells are taking the original values. Changing cells for each scenario are highlighted in gray.

Analysis of Sensitivity to Grain-meat Conversion Ratio

To analyze the sensitivity of total feed grain demand to the assumptions relating to the grain-meat conversion ratio and prospective structural change in the livestock production sector, we assess how feed demand changes if one of the following conditions change: (1) assuming the grain-meat conversion ratio for typical backyard hog production is lower than the current level, specifically if this is only half of the grain conversion ratios used in the current base estimation; (2) assuming only the commercial production mode exists and that the grain meat conversion ratios are closer to developed country standards, at 3.7 for pork production and 2.2 for poultry and egg production (GCR from Medrano and Bradford, 1999); (3) assuming the grain-meat conversion ratios for typical backyard and improved backyard modes are identical, with the grain meat conversion ratio moving higher, to 2.57 for pork and 2.08 for poultry and egg production; (4) the share of the backyard production mode increases by 5%; and finally, (5) the share of the backyard production mode decrease by 5%. The simulated results are presented in Table 5-17.

The sensitivity analysis indicates that projected total feed grain demand is very sensitive to the assumptions employed relating to the extent to which hog production is based on backyard modes of production relative to modern production technologies and the associated assumed grain-meat conversion ratio. If the grain-meat conversion ratios of typical backyard production practices for hogs decrease to half of its base estimation level, total feed grain demand projections decrease by 9 million metric tons in 2020 (Scenario 1). If the backyard production mode disappears and developed countries' grain-meat conversion ratios are applied, there would be a very large increase in feed grain demand. Total feed grain demand would increase by 33 million metric tons in 2020 (Scenario 2). If only the improved backyard production mode exists (Scenario 3), total feed consumption would increase by 14 million metric tons in 2020. Another factor that changes feed consumption demand is the percentage of modern (state/specialized production mode) production modes among all production modes. If the share of the modern production mode increases by 5%, total feed grain consumption will increase by about 4 million metric tons in 2020.

Table 5-17 Analysis of Sensitivity in Total Grain Demand to Grain-meat Conversion Ratio (GCR) and the Share of Modernized Production Mode

Scenario Summary		Base Estimation	(1)	(2)	(3)	(4)	(5)
Changing Cells:							
Typical GCR	Pork	1.80	0.90	3.70	2.57	1.80	1.80
Typical GCR	Poultry	1.60	1.60	2.2	2.08	1.60	1.60
Typical GCR	Egg	1.60	1.60	2.2	2.08	1.60	1.60
Improved GCR	Pork	2.57	2.57	3.70	2.57	2.57	2.57
Improved GCR	Poultry	2.08	2.08	2.2	2.08	2.08	2.08
Improved GCR	Egg	2.08	2.08	2.2	2.08	2.08	2.08
Share	Modern	30%	30%	30%	30%	25%	35%
Share	Modern	40%	40%	40%	40%	35%	45%
Result Cells:							
2005	TOTAL	365	360	389	372	364	366
2010		397	391	426	407	395	400
2015		439	431	471	451	436	442
2020		470	461	503	484	467	474
2005	TL Feed	99	93	123	106	98	99
2010		127	120	155	136	124	129
2015		161	153	193	172	158	164
2020		192	183	225	206	189	196

Notes: The Base Estimation column represents the original values associated with the base simulation. Changing cells for each scenario are highlighted in gray. Scenario (1) typical backyard GCRs drop to half of the base estimation; (2) western GCR; (3) only typical backyard production mode exists GCR; (4) lower share of modernized production mode; (5) high share of modernized production mode.

Sensitivity Analysis of Meat Consumption Structure Changes

To analyze the effect of meat consumption structure changes to total grain demand, we change the annual rate of increase in poultry consumption, thus changing the share of poultry and pork consumption. In the base estimation, annual rate of increase of poultry consumption is 1% in the urban sector and 1.5% in the rural sector (Table 5-18).

Table 5-18 Analysis of Sensitivity in Total Feedgrain Demand to the Structural Change of Meat Consumption

Scenario Summary			**(1)**	**(2)**
		Current Values	Slow Increase Rate	High Increase Rate
Changing Cells:				
Annual Rate of Increase of Poultry Consumption				
Urban		1.00%	0.50%	1.50%
Rural		1.50%	1.00%	2.00%
Share of Pork/ Poultry/ in 2020				
Urban		70%/30%	73%/27%	67%/33%
Rural		76%/24%	78%/22%	74%/26%
Result Cells:				
2005	**TL Feed**	98.53	98.53	98.53
2010		126.50	126.50	126.37
2015		160.93	160.93	160.60
2020		192.25	192.25	191.67
2005	**Pork Feed**	58.23	58.23	58.23
2010		72.73	72.73	71.69
2015		90.10	90.10	87.31
2020		105.18	105.18	99.96
2005	**Poultry Feed**	13.44	13.44	13.44
2010		17.92	17.92	18.83
2015		23.61	23.61	26.06
2020		29.02	29.02	33.66

Notes: Current Values column represents values of changing cells at time Scenario Summary Report was created. Changing cells for each scenario are highlighted in gray.

The share of poultry and pork in consumption in 2020 is 30% and 70% respectively for the urban sector; and 24% and 76% respectively in the rural sector in the base estimation. If the annual rate of increase of poultry consumption is increased to 1.5% and 2% respectively for urban and rural households, the share of urban poultry and pork in consumption in 2020 will be 33% and 67% respectively and 26% and 74% in rural areas. Increase in feedgrain used to feed the increased poultry associated with this change in consumption will be less than the feed savings from the decreased pork consumption, so total feed demand will decrease by 580 thousand metric tons in 2020. Feed grain use is not reduced under a low annual rate of increase in poultry consumption scenario.

5.4.4 Projection of Total Grain Demand Under Different Economic Development Scenarios

Total grain demand will change with changes in economic development. If the economy develops at a faster pace in the next twenty years, the demand for grain may increase due to rapid income increase and dietary changes; on the contrary, if the economy develops at a slower rate, the demand for grain may be lower. To simulate total demand in the next 20 years under different economic development paths, different assumptions of economic indexes, inflation rates, annual rate of income increase, and annual rate of population increase are considered in different scenarios.

High, medium and low grain demand scenarios are considered as listed in Table 5-19. The base estimation in Table 5-15 is the medium scenario, which is believed to be the most likely case. If income and population increase at higher rates than in the base scenario, while prices of grain, meat and spirits increase at a lower rate, the demand for grain will increase. This is termed the high grain demand scenario. If population and income increase at a slower rate than in the base scenario, and prices of grain, meat and spirits increase at a higher rate, the demand for grain will be lower. This is the low grain demand scenario.

Table 5-19 Projected Total Demand for Feed Grain and Total Grains in High, Medium and Low Scenarios: 2000 to 2020

Year	Scenario	Population --billion--	Feed Demand --mmt--	Total Demand --mmt--
	High	1.35	109	371
2005	Medium	1.33	99	365
	Low	1.32	90	363
	High	1.43	142	404
2010	Medium	1.40	127	397
	Low	1.37	96	357
	High	1.51	194	468
2015	Medium	1.47	161	439
	Low	1.42	108	368
	High	1.71	289	592
2020	Medium	1.46	192	470
	Low	1.55	132	401

Source: Simulation results.

1.High scenario reflects the high grain demand projections in 2005-2020, where the price of grain, meat and spirits increase at a lower rate, while income and population increase at a rate higher than the base estimation. High scenario will be the upper boundary of future grain demand.

2.Low scenario reflects the low grain demand projections in 2005-2020, where the price of grain, meat and spirits increase at a higher rate, while income and population increase at a rate lower than the base estimation. Low scenario will be the lower boundary of grain demand.

3.Medium scenario reflects the most plausible future grain demand in 2005-2020. The simulation is based on assumptions listed in Table 5-8 and Table 5-10.

In summary, there are three demand scenarios:

1. High grain demand scenario: Income increases at an annual rate of 5% in the rural and 6% in the urban sector; population increases at an annual rate of 1.1% in the period from 2005 to 2020.
2. Low grain demand scenario: Income increases at an annual rate of 1% in the rural sector and by 2% in the urban sector; population increases at an annual rate of 0.7% in the period from 2005 to 2020.
3. The medium grain demand scenario: Income increases at an annual rate of 3.3% in rural and 3.5% in urban households; population increases at an annual rate of 1% in the period from 2005 to 2020.

5.5 Grain Balance Sheets and Trade Implications

As the usage of grain for seed and other industrial purposes is quite small relative to total quantity, projection of these uses is not expected to significantly influence total projected grain demand. The total amount of industrial usage, plus seed demand, is less than 7% of total grain usage in 1998 to 2001 (Table A-1). To simplify the balance sheet calculations, assuming that all other usage besides human consumption and waste, due to transportation and other reasons, accounts for 7% of the total grain utilization.

The estimates of grain production by Huang and Rozelle (1999), Fan et al (1997(1)) and Simpson and Li (2001) are used to develop the output side of the grain balance sheets for the next 20 years for three import scenarios. Huang and Rozelle's (1999) projection is used as the baseline projection. High and low import scenarios are also assessed. The baseline projection of China's grain balance sheet is shown in Table 5-20.

Table 5-20 Baseline Projection of Grain Supply and Utilization: 2000-2020, Units: million metric tons

Year	Output	Total Demand			Surplus	Rate of Self-Sufficiency
			Consumption	Seed & Other uses		
2005	399	392	365	27	7	101.73%
2010	421	427	397	30	-6	98.52%
2015	456	472	439	33	-16	96.56%
2020	480	506	470	35	-26	94.93%
a.g.r[1]	1.16%	1.60%	1.60%	1.60%	-	-

[1] a.g.r. denotes annual growth rate. Source: Output projection numbers are from Huang and Rozelle (1999); total demand is from simulation results.

In the baseline projection, the total demand of grain is projected to be around 392 million metric tons in 2005 and to be 506 million metric tons in 2020, which represents an increase in total demand at an annual rate of 1.6%. If production of total grain increases at an annual rate of 1.2%, which would yield grain production levels of 399 million metric tons in 2005 and 480 million metric tons in 2020, China could still satisfy her domestic needs for grain in total until 2020 if 95% is considered as self-sufficiency. There will be a small deficit of grain in total since 2010 and the total deficit is projected to be 26 million metric tons in 2020.

The grain balance sheet for the high import scenario is constructed in Table 5-21. In the high grain import scenario, the total demand of direct and indirect grain consumption is projected to increase at 2.9% annually from 2005-2020. According to Fan et al.'s (1997 (1)) projection, total production of grain increases by 0.9% annually. This production increase cannot satisfy the increased demand, leading to large deficits of grain.

Table 5-21 High Grain Import Scenario: 2000-2020, Units: million metric tons

Year	Output	Total Demand			Deficit	Rate of Self-Sufficiency
			Consumption	Seed & Other uses		
2005	392	399	371	28	-7	98.15%
2010	417	434	404	30	-17	96.06%
2015	433	503	468	35	-70	86.00%
2020	449	636	592	45	-187	70.58%
a.g.r[1]	0.85%	2.95%	2.95%	2.95%	-	-

[1] a.g.r. denotes annual growth rate. Source: Output projection numbers are from Fan et al (1997(1)); Total demand projection is from simulation results.

Using the prediction of grain production by Simpson (2001), the grain balance sheet for the low grain import scenario is constructed in Table 5-22. Since Simpson's prediction uses the Chinese State Statistical Bureau (SSB) data, these are adjusted downward using a factor of 0.85 to be comparable (Chapter 2, 24). In the low grain import scenario, total production of grain is projected to increase at 1% annually from 2005 to 2020; and the total demand of direct and indirect grain consumption is projected to increase at 0.62% annually from 2005 to 2020. A large surplus in grain in total is projected for 2020.

Table 5-22 Low Grain Import Scenario: 2000-2020, Units: million metric tons

Year	Output	Total Demand			Surplus	Rate of Self-Sufficiency
			Consumption	Seed & Other uses		
2005	417	390	363	27	27	106.90%
2010	440	384	357	27	56	114.67%
2015	462	395	368	28	67	116.91%
2020	491	431	401	30	60	113.95%
a.g.r[1]	1.03%	0.62%	0.62%	0.62%	-	-

[1] a.g.r. denotes annual growth rate. Source: Output projection numbers are from Simpson and Li (2001); the total demand projection is from simulation results.

Assuming that maize output will be used as feedgrain and that maize will be the major component of feedgrain, a tentative feed grain balance sheet can be constructed for the low grain import scenario as in Table 5-23. Fan et al. and Huang and Rozelle did not separate corn production from other grains, so only Simpson and Li's production projection is used in this feedgrain simulation.

Table 5-23 Projected Feed Balance Sheet 2005-2020, Units: million metric tons

	Feed Supply	Feed Demand	Feed Deficit
2005	119	99	20
2010	*130*	126	4
2015	140	161	-21
2020	*154*	192	-38

The italic number in the output column is the simple moving average of Simpson et al.'s estimation.

The feed balance sheet in Table 5-23 suggests that China can satisfy domestic feed grain demand until 2010. There will be a surplus of feed grain output in the near future. Growing imports are expected after 2010.

Based on the baseline projection of grain supply and utilization (Table 5-20), which is considered most probable, there will be deficit of grain in total. Current stock levels are quite high (USDA, 2002), so the deficit can be supplied partly from stocks as well as minor imports. The import amount can be expected to be volatile—from 1 million metric tons to 20 million metric tons—depending on storage needs and decisions. Generally speaking, there will be modest, but growing, net imports of grain from the next decade under the conditions of the baseline scenario and if the Chinese economy develops as projected.

5.6 Discussion

Comparison of the estimation results of this study with those from other studies, which were given earlier in Table 2-5, indicates that the estimates of the derived demand for grain tend to be appreciably lower than many other predictions. A major reason for this difference is that projected feed grain demand in this research is lower than other projections, since this research emphasizes the role of the traditional production mode in China's livestock production.

A further issue is the degree to which the simulation projections reported in this chapter, especially for 2005, reflect recent grain production and consumption events in China. According to recently published USDA data in 2004 (Table A-8), total grain production has continuously decreased since 1999. In 2003, grain production could only satisfy 80% of domestic consumption. Grain stocks are being called on to compensate, in part, for recent falls in grain output. If production cannot return to 370 million metric tons, China will need net imports of grain, particularly, wheat, in 2005.

Predictions of supply by other researchers are erratic, depending on assumptions of cropped area, and investments on irrigation and agricultural research. Investments on irrigation and research will eventually determine yields of grain. Huang and Rozelle (2003) indicate the possibility of yield increases due to investment on irrigation and research development. Zhang and Fan (2001) argue that China may have greater grain production potential than previously thought. However, Rosegrant and Cai (2002) predict that production will fall because of groundwater overdraft.

Decreased total grain output in 2003 is the direct result of the decreased acreage of major crops (Table 5-24). Acreage decrease could be caused by urbanization, and could also be an economic reaction to market information as farmers allocate land to more profitable products. Since grain self-sufficiency is a very sensitive issue in China, the shortfall of grain supply can be expected to bring the attention of the Government of China back to grain production again.

Migration is not included as a determinant of foodgrain demand in Chapter 3, but this is considered in the simulation work in this chapter. If urbanization is included, the composition of grain import might be changed not only by growth in family income and price changes as analysed, but also by differences in urban and rural lifestyles, the development of more advanced marketing systems, and occupational changes that are closely linked with increasing GNP per capita (Huang and Bouis, 2001). Research done by Huang and Bouis (2001) on Taiwan's experience from the period of 1981 to 1991 indicated that rice consumption declined by one-half in that period. During the same period, consumption of wheat, meat, fish and fruits increased. The authors (Huang and Bouis, 2001) suggested that these trends could happen in other Asian countries.

However, there is another noticeable difference between the economy of Taiwan and that of Mainland China. After the Revolution in 1949, China was a planned economy for more than 30 years. Since the change to an increasingly market-oriented economy, beginning in the mid-1980s, the desires of Chinese consumers for greater food diversity have led to increases in rice consumption in large areas of northern China. Wheat had been the main output and rice was not always available in northern areas under the planned economy (Carter and Zhong, 1999). In southern China where rice was overwhelmingly dominant in the production and consumption of food, the reverse was true: consumers, especially in urban areas, began diversifying their diets with increased consumption of wheat These two patterns of diversification will influence the composition of direct food demand. Canada might enjoy the expansion of wheat import demand in China if the switch to wheat in southern China is the stronger of these two diversification forces.

The impacts of China's WTO accession are not included in the simulation. Comparative advantage in grain production and possible impacts of the WTO on China are discussed in the next chapter.

Table 5-24 Harvest Area and Yield Change for Major Crops in 2003

	Maize	Wheat	Rice	Output
Change of Harvest Area (million Hectares)	-1.1	-1.9	-1.1	-19.5
Yield (Hg/Ha)[1]	4.8	3.9	6.1	

Source: Computed by author from FAOSTAT database. Units are hectogrammes (100 grammes) per hectare (Hg/Ha)

CHAPTER 6 IMPLICATIONS OF WTO ACCESSION TO CANADA-CHINA GRAIN TRADE

6.1 Introduction

The simulation analysis reported in Chapter 5 views import demand as the difference between production and consumption. Issues relating to international prices and comparative advantage are not considered. Since China's accession to the World Trade Organization in 2001, China's economy is moving to a more formal phase of integration into the world economy. The system of rules governing world agricultural trade since the Uruguay Round of world trade negotiations has required countries to convert non-tariff barriers to systems of tariff-rate quotas (TRQ). China committed to progressively liberalize the availability and scope of the right to trade so that within three years after accession all enterprises would have the right to import and export goods, with the exception of specified shares of listed products, many of which are agricultural products. China's trade regime will largely be based on the usage of tariffs for import protection, and all tariffs will be bound. TRQ will apply to wheat, corn, rice and edible oils, sugar and cotton. Substantial reduction in trade barriers in China can be expected to have impacts on both China itself and the global economy.

Currently, all TRQ commodities, except for wool, are imported on a sole-importer basis by state traders. Martin (2001) pointed out that state trading enterprises (STEs) should essentially be free to choose the quantities that they import, subject to meeting market demand at a domestic price that should reflect the import price plus the bound tariff.

In the following sections of this chapter, we briefly review the policy changes that China made to prepare for membership in the WTO. This is followed by an overview of literature that assesses the economic impact of China's WTO accession. We then assess recent and prospective patterns of trade flows between Canada and China. Despite recognizing that the impacts of WTO accession will take some time to be evident, the values of trade before and after the accession of WTO are briefly compared. Possible implications for Canada-China grain trade are raised.

6.2 Tariff and Non-Tariff Protection

Before the accession of China to the WTO, tariffs had little if any effect on the pattern of imports by China. Physical quantities of individual imports were determined in the planning process, and most imports were sold at the same prices as comparable domestic goods. Accession to the WTO is expected to be a critical turning point for trade with China, leading to more transparency and providing for disciplines on protection, even for the commodities remaining under state trading.

In joining the WTO, China committed to phase out import and export licenses and other administrative protection methods, instead introducing a system of tariff rate quotas for import protection. For agricultural products, there are quotas on the volume of imports. Once the quota is filled, the higher tariff is applied on additional imports. Table 6-1 lists the Most Favored Nation (MFN) tariff rates associated with the tariff-rate quotas for selected agricultural products.

Table 6-1 China's Tariff Rate-Quota Commitments, Most Favored Nations

Products	Tariff item number	Proposed quota quantity and in-quota tariff rate	Final quota quantity and conditions	Implementation period	Other terms and conditions
Wheat		7,884,000 mt	9,636,000 mt		1) STE share = 90%
	Durum wheat	1%	1%	2004	2) Staging of TRQ quantity:
	Wheat, meslin	1%	1%		Year: TRQ quantity:
	Wheat or meslin flour	6%	6%		2002: 8,468,000 mt
	Meal of wheat	9%	9%		2003: 9,052,000 mt
	Pellets of wheat and of other cereal	10%	10%		2004: 9,636,000 mt
Corn		5,175,000 mt	7,200,000 mt	2004	1) STE share = 71% to 60%
	seed not sweet	1%	1%		2) Staging of TRQ quantity:
	Not seed	1%	1%		2002: 5,850,000 mt
	Corn flour	9%	9%		2003: 6,525,000 mt
	Meal of corn	9%	9%		2004: 7,200,000 mt
	Worked corn	10%	10%		3) Staging of STE share:
					2002 68%
					2003 64%
					2004 60%
Rice		1,662,500 mt	2,660,000 mt	2004	STE share = 50%
	Paddy rice	1%	1%		1) Rice products are included in the short medium grain rice;
	Paddy rice	1%	1%		2)Quota for short & medium grain rice shall be allocated to state enterprises and to private sectors at a ratio of 50:50;
	Wholly milled rice	1%	1%		3) Staging for the TRQ quantity:
	Broken rice	1%	1%		Year: TRQ quantity:
	Rice flour	9%	9%		2002 1,995,000 mt
					2003 2,327,500 mt
	Rice meal	9%	9%		2004 2,660,000 mt

Source: World Trade Organization: China's Goods Schedules

The bound tariff rates are the maximum tariff rates China can impose prior or during trade negotiations; these are the over-quota tariff rates as provided under the Uruguay Round Agricultural Agreement (URAA). The simple average tariff binding on agricultural products after accession was estimated to be 17 percent (USTR, 1999). China committed to significantly reduce the nominal tariffs to bring the average tariff level to less than 10 percent by 2005. Table 6-2 lists China's negotiated bound tariff rates for selected agricultural products.

Table 6-2 Bound Rates of Duty on Selected Agricultural Products, China

HS	Description	Bound rate at date of accession	Final bound rate	Implementation Date	INC[2]
1001	Wheat and meslin:				
	10011000 Durum Wheat	74	65	2004	CA,US
1005	Maize (corn):				
	10051000 Seed	32	20	2004	US
	10059000 Other	74	65	2004	US
1006	Rice:				
	- Rice in husk (paddy or rough):				
	10061010 -Seed	74	65	2004	AU,US,UY
	10061090 -Other	74	65	2004	AU,US,UY
1007	Grain sorghum:				
	10070010 -Seed	0	0		CA,US
	10070090 -Other	2.6	2	2004	CA,US
1101	Wheat flour:				
	11010000 Wheat flour	74	65	2004	AU,US
1003	Barley:				
	10030010 Seed	3			AU,CA,US
	10030090 Other	3			AU,CA,US
1004	Oats:				
	10040010 Seed	0			AU,US
	10040090 Other	2.6	2	2004	AU,US

1. The "final bound rate" of duty, if differing from the "bound rate at date of accession", will be implemented according to the date specified in the "implementation" column. The implementation column indicates the date, referring to 1 January of the year indicated, when the final bound rate will be achieved.
2. INC indicates initiated country.
3. Source: World Trade Organization: China's Goods Schedules

The difference between in- and out-of-quota tariffs is the largest for the major grains—wheat, maize and rice (Table 6-1 and Table 6-2), which are important products in China's trade. In 2002/03, China imported 2.0 million metric tons of wheat, 0.1 million metric tons of corn and 0.1 million metric tons of rice, all below the quota amounts. Currently, grain import quotas are not restrictive. China's import quantities of wheat, corn and rice and the TRQ for these for 2002 are listed in Table 6-3.

Table 6-3 2002 Grain Imports and Tariff Rate Quotas (million metric tons)

	Wheat	Corn	Rice
Tariff Rate Quota[1]	8.47	5.85	1.99
Actual Import[2]	2.00	0.10	0.12
Ratio of Import/Quota	23.61%	1.71%	6.03%

Source: 1. World Trade Organization: China's Goods Schedules; 2.USDA/ERS

6.3 Possible Implications for Canada's Exports

In the long run, with China more integrated into the world trading economy, whether China will provide more grain trade opportunities to the world, including Canada, will depend on the comparative advantage between China and other countries. China has only 7% of the world's land, and 20% of the world's population with almost the same land area, Canada's population is less than 32 million, less than 1% of the world's population. It seems obvious that China is most unlikely to have a comparative advantage in producing land intensive goods, while Canada is unlikely to have a comparative advantage in producing labor intensive goods.

Figure 6-1 (pp. 195) illustrates trade between two countries (Houck, 1986). In a two country one-commodity world, country 1 has excess demand and country 2 has excess supply. The transfer costs are assumed to be zero; equilibrium exists where the excess supply of county 1 is equal to the excess demand of country 2.

6.3.1 Trends in China's Wheat Markets and Implications for Canadian Wheat Exports

Fang and Beghin (1999) assessed China's comparative advantage in major agricultural crops based on a modified policy analysis matrix (PAM) using data for 1996. Their results suggest that grain (wheat, corn, and sorghum) and oilseed crops (soybeans and rapeseeds) are less profitable than are fruits and vegetables, tobacco, sugarcane, cotton and rice. Among the grain and oilseed crops, rice is the only crop for which China exhibited relative efficiency. These conclusions are consistent with analysis by Huang and Rozelle (2001). They ranked China's grain production activities from comparative advantage to disadvantage as: Japonica rice, sorghum, middle Indica rice, millet, late Indica rice, early rice, corn, soybean, and wheat. It would be more profitable for China to import wheat from the international market than to produce this product.

Table 6-4 Market Share of Canada in China's Cereal Imports (percentages of total value of imports): 1995-2001

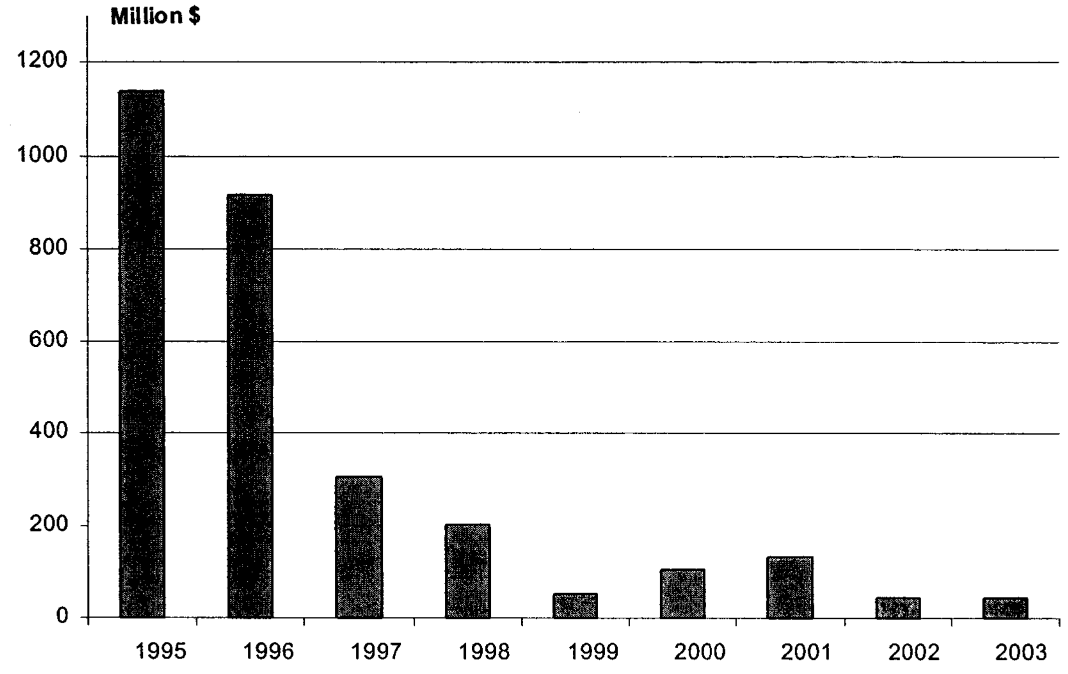
Share	1995	1996	1997	1998	1999	2000	2001
Cereals	25	31	37	27	14	23	32
Wheat	41	36	61	49	40	48	71
Barley	26	41	28	21	11	20	28
Rice	-	-	-	-	-	0	0

Source: Estimated by author. Chinese data are from China's Statistical Yearbook, various issues. Canadian data are from Statistics Canada.

Canada is traditionally one of China's largest wheat suppliers. The average value of China's wheat imports from Canada during the years from 1995 to 2003 amounted to 328 Canadian million dollars. Canada was the major source of China's wheat imports. The value of total wheat imports in 2001 by China amounted to $C 187 million dollars, 72% of which was imported from Canada. Figure 6-2 illustrates the values of Canada's wheat exports to China from 1995 to

2003. Table 6-4 lists the value share of Canadian cereal in China's total wheat cereal imports.

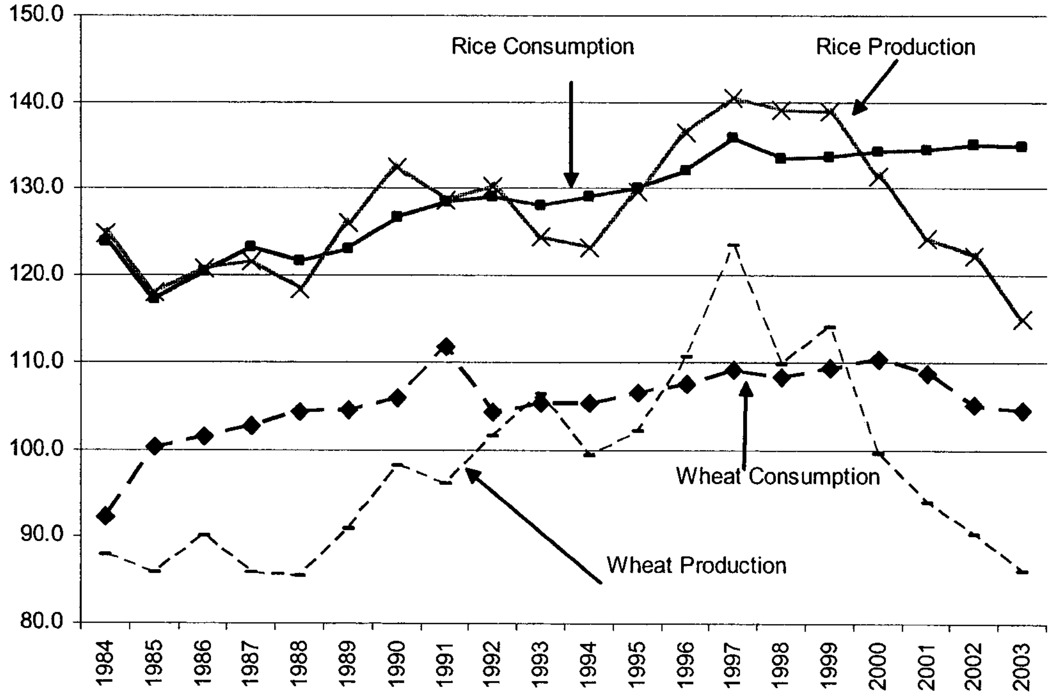
Figure 6-2 Canadian Wheat Exports to China: Value of Exports in 1995 – 2003 ($ C million)



Source: Statistics Canada

Canada's leading position in China's wheat import market requires awareness of preferences and demand in China's market. Data on total wheat and rice consumption since 1994, illustrated in Figure 6-3, suggest two major trends: First, total domestic wheat production has been volatile and generally below the level of domestic consumption except in the period from 1996 to 1999. There was a shortage of 19 million metric tons in 2003. Second, rice consumption is steadily increasing, while wheat consumption is declining. The share of wheat consumption in total fine grain consumption (wheat plus rice) declined from 46% in 1985 to 44% in 2003. If these data are correct, China had a shortage of 15 million metric tons of wheat each year on average during the period illustrated. USDA has projected the existence of large stocks of domestic wheat, suggesting that there may not be immediate increases in importation, though a larger import potential seems evident.

Figure 6-3 China's Total Wheat and Rice Production and Consumption: 1984-2003. Units: Million Metric Tons



Source: ERS/USDA (2004)

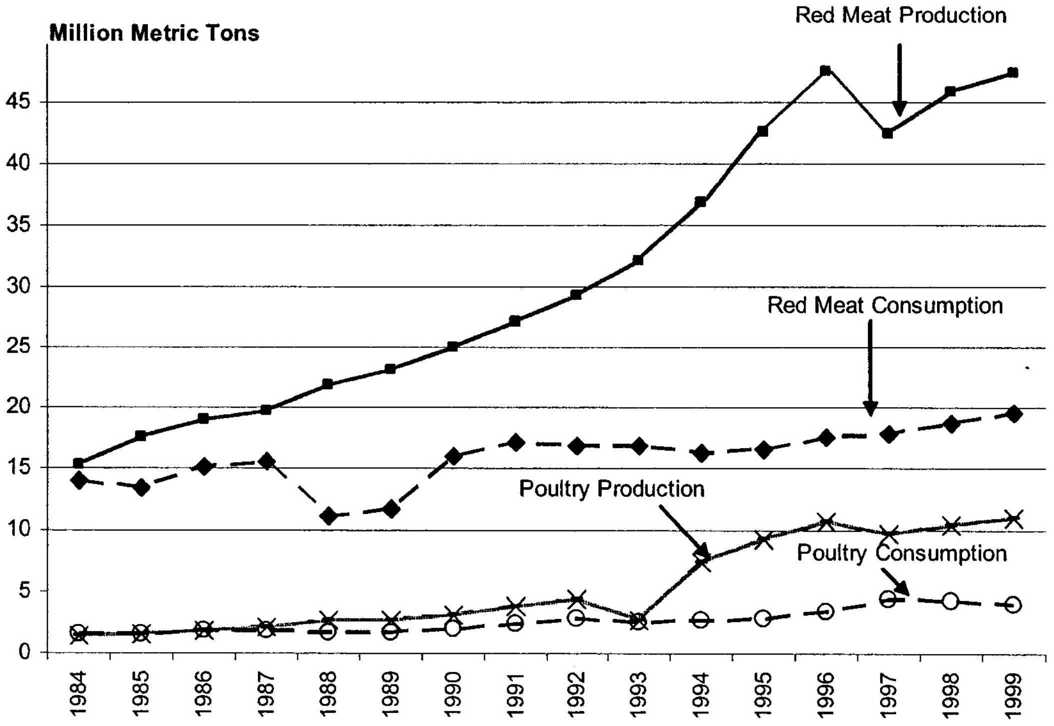
From the projections in Chapter 5, China's total domestic food grain demand will reach 256 million metric tons in 2015 (Table 5-15). If the share of wheat is 44%, China's wheat consumption will reach 113 million metric tons, a 10 million metric ton increase from 2003. China's domestic production cannot grow fast enough to satisfy this increase, especially for low and high protein wheat (Agricultural and Agri-Food Canada, 2002). China's domestic wheat production has been dominated by medium protein varieties for the past 40 years, and maximizing yields was a primary concern. With the shift to a more consumer oriented system, low and high protein wheat, which are suited to produce western style cakes, cookies and breads, can be anticipated to be in higher demand. Canada's Canada Western Red Spring (C.W.R.S.), which has higher levels of protein than Chinese wheat, forms the largest part of wheat exports to China. China's imports of C.W.R.S. from Canada averaged 2.8 million metric tons per year during the period from 1990/01 to 2000/01. Durum wheat accounts for a negligible portion of Canadian wheat exports to China.

6.3.2 Trends in China's Livestock Market and Implications for Canadian Cereal Exports

According to the assessment by Tuan et al (2001), for the period from 1990 to 1998, production of hogs (in backyard production activities), beef cattle (in rural household production), and broilers (in specialized household production) was fairly competitive relative to import sources. Tuan et al estimate that China had a strong comparative advantage in producing in these three livestock activities. This conclusion is consistent with China's continuation as a net exporter of livestock products, despite the rapid increase in domestic consumption levels both in urban and rural areas (Figure 6-4).

Figure 6-4 indicates two trends in China's livestock market: first, during the period from 1984 to 1999, consumption of both red meat and poultry increased, particularly for poultry consumption. Second, growth rates of livestock consumption significantly lagged behind the growth in meat production. From household survey data information for China, published by USDA, it is estimated that meat consumption away from home accounted for 10% of total meat consumption in 1997 (USDA/ERS, 1999).

Figure 6-4 China's Total Red Meat and Poultry Production and Consumption: 1984-1999 Units: million metric tons



Sources: SSB, China's Statistical Yearbook, various issues.

As discussed in Chapter 5, this study projects that total red meat and poultry consumption will reach 52 million metric tons by 2020 (Table 5-13), which could be satisfied by current production levels. It is predicted that poultry demand will increase more than pork, so that in 2020, poultry consumption will reach 14 million metric tons, 3 million metric tons more than current production levels. Due to their taste preferences, Chinese consumers tend to favor cuts that are less desired in Western markets, including internal organs and chicken feet. Prices for bone-in chicken feet are generally higher than chicken breast meat (Hayes, 1997). If these tastes continue, there could be an import market for variety meats.

The value of total meat exports from Canada to China is less than 1% of the value of China's meat imports. In 2003, China's meat imports from Canada were valued at $C 27 million dollars, 76% of this was pork and frozen swine, 18% was poultry meat and about 4% was frozen beef. The value of Canadian meat exports to China is low and the variety is very limited.

Even though relatively little meat is exported from Canada to China, the expected rapid growth in meat production in China implies a large market for feed grain. As noted above, China does not have a comparative advantage in producing coarse grain (corn and sorghum), or oilseeds (soybean and rapeseed). In livestock production, corn is a major energy source and soybean is the major protein source (Simpson et al. 1994). This study predicts feed grain demand will be 192 million metric tons in 2020 (Table 5-15), almost double the current level. The demand for soybeans will increase proportionally. It is of importance that there is no TRQ restriction on the import of soybean and other beans. Import demand is likely to increase in future years.

Another major change affecting grain use in China is the rapid increase in beverage consumption (Table 5-18). Canada is one the largest exporters of malting barley to China. The value of China's barley imports from Canada were as high as $C170 million dollars in 1996.

6.4 Summary

Agriculture exports from Canada to China are focused on wheat and barley. After China joined the World Trade Organization (WTO), the within quota tariff for wheat was reduced greatly to 1% ad valorum. In 2004, the tariff rate quota is 9.6 million metric tons.

Even though the tariff rate quota has not been filled since China's accession to the WTO in 2001, in the long run, China does not have a comparative advantage in producing wheat. From 1984 to 2003, the annual wheat deficit averaged 10 million metric tons. Wheat consumption is estimated to increase by another 10 million metric tons in the next 20 years. Unless there is a substantial increase in wheat production, there will be an increasing market for Canada.

The rapid increase in livestock consumption has lagged significantly behind production increases. However, in contrast to the grain sector, China's backyard style of livestock production still has a strong comparative advantage. This, together with import tariffs and sanitary restrictions, suggests that the exports of meat to China are unlikely to increase appreciably in the near future. However, increased import demand for coarse grain to support the rapid growth of livestock production is expected.

Compared with wheat, corn and rice, China applies less control on such other crops as soybeans, sorghum, barley and oats. China has no tariff rate quota restrictions on soybean import. Import tariffs for sorghum, barley and oats are as low as 2% or 3% ad valorem. There are prospects for increased exports of these crops to China.

CHAPTER 7 SUMMARY AND POLICY IMPLICATIONS

7.1 Introduction

This chapter summarizes the major conclusions of the study. General policy implications from the research are outlined. Contributions and limitations of the research, and suggestions for future research, are also discussed in the chapter.

7.2 Analysis of China's Grain Demand

Many analysts predicted that China would become a larger importer of agricultural products following its accession to the World Trade Organization (WTO). However, during 2002, its first year as a WTO member, China actually became a larger net exporter of agricultural products. Increased exports of corn and horticultural products (vegetables, fruits, nuts, and their products) accounted for over $1 billion of China's $15 billion increase in agricultural exports during 2002. Corn exports reached a record of 11.7 million tons during calendar year 2002 (USDA/ERS, 2003).

There are problems in the accurate estimation of future demand for meat and the related demand for feed grain in terms of the current style of meat production in China. There are many ways to estimate future consumption. Davis (1997) suggested that dynamic and other time-varying models are good choices in situations like China. Partial adjustment models are particularly useful in demand analysis in situations where consumption cannot fully adjust to desired levels due to rigidities in institutions or other features that may cause lags in consumption behavior.

In terms of data on consumption levels, prices and income for grain and grain-based products, initial unit root tests of stability in these series showed that these data are non-stationary and all have unit roots. The partial adjustment model was therefore evaluated and applied in error correction functional form to avoid over-differencing due to co-integration among consumption levels, prices and income.

The income elasticity estimates for rural food grain consumption varied from zero to 0.35 for the short-run estimates and from 0.01 to 0.40 for the long-run estimates, indicating that directly consumed food grains are necessities and normal goods. The estimated income elasticity estimates of urban food grain consumption varied from 0.11 (the short run estimate) to 0.31 (the long run estimate) before the 1978 reforms, but were negative after these reforms. This implies that food grain is becoming an inferior good for urban households. However, some analysts of Chinese urban grain demand tend to believe that although the income elasticity for urban food grain is declining, these are still small and positive when more detailed regional data are used in the analysis (Wang and Kinsey, 1994; Zhang et al, 2001). Income elasticity estimates for meat consumption varied from 0.22 (the short run estimate for the rural model) to 1.21 (the long run estimate for the urban model). Income elasticity estimates for spirits consumption varied from 0.21 (short run estimates) to 1.29 (long run estimates). Meat and spirits are relatively more income elastic than food grain. All price elasticity estimates are less than 0.5 in absolute value except for spirits consumption in rural households, which is -1.21, suggesting that food grain and meat are relatively basic goods in China whereas spirits are luxury consumption goods for rural households (Table 3-20).

The coefficient on the error correction term, which indicated the adjustment from short run to long-run equilibrium consumption levels, indicates a more rapid adjustment for spirits than is evident for food grain or meat. The analysis also showed that the adoption of the household responsibility system in 1978 has greatly improved people's livelihoods in China, which is reflected in the substantial increase in per capita food grain, meat and spirits consumption levels.

7.3 Forecasting Per Capita Grain Demand

Research reported in the literature has suggested that traditional time series analysis, as with a Box-Jenkins (1976) type model, for example, can provide better econometric properties, but is sometimes poorer in prediction (Engle and Watson, 1985; Conway el al, 1987). Harvey and Todd (1983) suggested that state space models, which allow for one or more variables changing with time, provide comparable forecasts to the Box-Jenkins approach and can provide more detailed information in forecasting. ARIMA models can be written and estimated as special cases of a state space specification. These approaches are attractive because the change in grain policy and consumption behavior changes in China are difficult or impossible to capture with fixed parameter models.

The application of recursive residual tests suggested that the parameters in a fixed parameter approach are not constant, leading us to develop a state-space model, using Kalman filter estimation, to re-estimate grain consumption demand. The time-varying parameters in this estimation are price and income elasticities, with state variables following an AR(1) process. The estimated average income and price elasticities are listed in Table 4-3. The smoothed state variables indicate the adjustment of the price and income elasticities.

The within-sample prediction values of per capita grain, meat and spirits demand from the time-varying parameter models were compared in Figures 4-5 to 4-10. It is concluded that the time-varying parameter models provide better within sample predictions than partial adjustment models, except in the case of rural meat demand.

Out-of-sample forecasts for the period from 1995 to 1999 are derived for each of the time-varying parameter and partial adjustment models. The underlying models are then re-estimated using data only from 1952 to 1994 and these estimates are used to forecast for the subsequent period to 1999. The forecasts are compared, as are the root mean squared error (RMSE) statistics of the out-of-sample forecasts. The forecast using the Kalman filter generally showed smaller Root Mean Square Errors in out-of-sample forecasting. The predictions from the time-varying parameter models were superior in forecasting than the partial adjustment model.

The estimated time-varying parameter models are then used to forecast per capita food grain, meat, and spirits demands for the subsequent twenty years to 2020. Based on assumptions for economic growth and the rate of population increase, projections of aggregate grain demand for food, feed and spirits are simulated.

7.4 Chinese Grain Balance Sheet and Import Demand

In Chapter 5 a simulation model is applied to develop grain balance sheets for total grain, as well as for feed grain, and to explore the possibility of grain self-sufficiency in China. The simulation incorporates prediction results from Chapter 4 and assumptions of parameters of other major influences on consumption and import demand.

On the consumption side, focus is put on feed grain demand increases that are associated with the increasing demand for meat. The grain-meat conversion ratios and different meat consumption patterns are key parameters to the projection of future feed grain consumption demand.

The grain-meat conversion ratio adopted in many previous studies was very close to western standards, at 4.14 and 3.20 respectively for the pigmeat and poultry grain-meat conversion ratios. However, if the grain-meat conversion ratios of the backyard production mode, which is still the prevalent production mode in China, accounting for 70% of total meat production, are taken into consideration, the western standard is obviously too high.

Considering traditional modes of meat production, China's feed grain demand will be less than predicted by many economists. If the objective to encourage grain self-efficiency is pursued, the Government of China might encourage a change in meat consumption patterns from high grain-based meats, such as beef and pork, to low grain-based meats, such as poultry and fish.

Household survey data on backyard livestock operations of Simpson et al. (1994) indicate that unprocessed grain only accounts for 46.3% of total livestock feed, with the balance provided by green feeds plus waste products and bran.

Consequently, we adjust the grain-meat conversion ratio leading to adjusted estimates of 1.8 and 1.6 for backyard production of pigmeat and poultry respectively. Using these estimates of the grain-meat conversion ratio, livestock feed consumption represents only 80% of current feed grain consumption use.

We arrive at projections of feed grain consumption demand as 99 million metric tons for 2020 when the adjusted grain-meat conversion ratios are applied, compared with 123 million metric tons when the grain-meat conversion ratios of developed countries are used. Total grain consumption demand is projected to be 365 million metric tons in 2005 using the adjusted grain-meat conversion ratios, which would increase to 389 million metric tons if the grain-meat conversion ratios of developed countries were applied.

The estimate that supply and demand for total grain will be marginally balanced in 2005 hinges mainly on the supply of grain. Even so, the increase in feed consumption demand is expected to lead to feedgrain deficits in 2015.

If the economy grows at a high rate, and there is a high rate of increase of population, the demand for grain will increase appreciably. Under these assumptions, total grain consumption is projected to be 399 million metric tons in 2005, and 636 million metric tons in 2020. In this scenario, China would have to import a large amount of grain from the international market (Table 5-21).

If the economy grows at a low speed with low increases in income and population, while there is at a high rate of price increase, the demand for grain will grow at a relatively low rate. In these circumstances, total grain demand will be 390 million metric tons in 2005, and 431 million metric tons in 2020, leading to a grain balance sheet surplus (Table 5-22). Currently, China's economy is growing at a medium to high speed, suggesting that the low economic growth scenario is unlikely.

7.5 WTO Accession Implications to Canada-China Grain Trade

In 2001, China became a member of the World Trade Organization. China has made many changes in institutions and regulations to satisfy WTO requirements since first applying to join the WTO in 1985. Currently, trade in agricultural products is conducted by trading companies, most of which are state owned. Key agricultural products, including grain, cotton, oil and wool, are state traded. The Cereal, Oil & Food Stuffs Importing and Exporting Corporation (COFCO) is China's largest agricultural state trading enterprise, and plays a key role in China's food trade. With accession to the WTO, China committed to increase the share of non-state trading in tariff rate quota import allocations. In 2002, 90% of the wheat import quota was allocated to the state trading company. It is expected that trading rights will be decentralized gradually, including extending trading rights to some joint ventures and private companies in the special economic zones. In three years after accession, all enterprises are to have the right to import and export all goods.

The bound tariff rates for selected agricultural products arising from the WTO negotiation are shown in Table 6-2. The within-quota tariff rate for Most Favored Nations (MFN) is low (Table 6-1). For example, for wheat, the within quota tariff rate is 1%. However, the TRQ in 2002 was largely unused. China's importations of wheat, corn, rice and rapeseed oil were less than 10 percent of the respective quotas.

China is a major export destination for Canada wheat and barley. In 2001, China was the third largest export destination for Canada wheat. In 2001, wheat imported from Canada accounted for 71.2% of the value of China's total wheat imports. The "moderate" prediction that wheat consumption will increase by 10 million metric tons by 2020 would require increased importation of wheat from the international market, to the benefit of Canada.

Rapid increases in meat consumption will provide more trade opportunities for feed grain exports to China. This market will increase in importance in the next two decades. Demand for coarse grains (corn, barley, sorghum), and oil seed crops will increase.

Reflecting a traditional orientation to a grain self-sufficiency policy in China, key grain products, including wheat, rice and flour, are expected to be carefully monitored. Even so global increases in market access under minimum access opportunity commitments for wheat, coarse grain and corn will increase trade opportunities for Canadian cereal exports.

7.6 Conclusions and Policy Implications

China's grain consumption demand is an issue of much interest to agricultural economists. With a population of more than one billion people, changes in grain and food consumption levels can appreciably influence the world grain market. Predictions from this study indicate a slow decrease in per capita food grain consumption demand during the period from 2005 to 2020 with dietary changes. Per capita food grain consumption is projected to be 82 kg/capita in urban areas and 239 kg/capita in rural area in 2005. Meat consumption is projected to increase at an annual growth rate of 3.1% and 3.2% respectively for the urban and rural sectors during the period from 2005 to 2030. Per capita meat consumption is projected to be 26.15 kg/capita and 18.39 kg/capita respectively for the urban and rural sectors in 2005. Spirits consumption is also projected to increase at a relatively high rate. Per capita spirits consumption is projected to have a growth rate of 2% and 3.8% for urban and rural residents, respectively. The levels of spirits consumption are projected to be 10.8 kg/capita and 11.2 kg/capita for urban and rural residents, respectively, in 2005.

A rapid increase in aggregate meat consumption will encourage the trend of livestock expansion, in accordance with most economists' predictions. However, a surge in feed grain consumption demand will be much slower to be evident than originally thought by many analysts. We analyzed future feed grain consumption based on careful assessment of China's current styles of livestock production. The prevalent style of backyard production is expected to continue and will probably account for no less than 50% of total production in the next 20 years. The backyard style of livestock production is quite different from the modernized style of production. Table wastes, green feed and other non-grain feed are likely to continue to account for more than 50% of total feed composition in this production technology. The adjusted grain-meat conversion ratio is as low as 1.8 for pigmeat production and 1.6 for poultry production in the backyard mode of production. Based on adjusted grain-meat conversion ratios, simulated feed grain usage in 2005 can be as low as 99 million metric tons. If the grain-meat conversion ratios in developed countries are applied, this alone would increase feed grain usage to more than 123 million metric tons in 2005, a difference of almost 25 million metric tons.

Based on our estimates of the most likely situations, immediate grain consumption shortages will not be caused by surges of feed grain demand to meet increased demand for livestock products.

China is expected to continue its policy favoring grain self-sufficiency. Import and export of the key commodities associated with basic food security is likely to be closely monitored. Import or export of these beyond certain ranges might stimulate policy changes to give incentives to production or suppress demand. The tariff rate quotas are not a current restriction to grain imports and, there is still much room in these.

The analysis leads to the following observations and suggestions relative to future policy. China's domestic supply of wheat is short in supply and primarily composed of medium protein varieties that have dominated domestic production for the past 40 years, due to a desire to maximize yields. Higher quality wheat, including both high and low protein wheat, have advantages to millers in terms of production of flour for western style cakes, cookies and breads which have increased in popularity in recent years, and also to improve the quality of traditional noodles, dumplings and steamed breads. Wheat varieties that satisfy these kinds of needs may be of increasing interest in China. Also of interest is that there are no tariff-rate quota restrictions on importation of minor crops, such as oats and corn. In general, and likely of most importance in the long run, China is expected to rely increasingly on cereal importation to meet domestic requirements. Research focused on this market will have long term benefits to agricultural exporting countries, such as Canada.

7.7 Contributions, Limitations and Suggestions for Future Research

This research project attempts to estimate grain demand and to predict future grain import demand for China. It builds and applies time-varying parameter demand models, using Kalman filter algorithms, to analyze and project future grain demand. This is one of the initial research studies to apply state-space models to analyze and forecast agricultural demand in China. The estimation results are compared to those from frequently used partial adjustment models of demand (frequently used because of the lags and impediments to adjustment in a planned and transitional economy). Overall, the time-varying parameter model provides better prediction results.

Another contribution of the study is the emphasis on the livestock feed technology of different modes of livestock production in the context of a simulation model to project future grain consumption. The nature of the feed conversion ratio is an issue that has received little emphasis in previous studies. The adoption of an appropriate grain-meat conversion ratio to project future feed grain demand can be expected to lead to improved forecasts of grain import demand. This will in turn help analysts and policy makers to better understand the world grain market and correctly identify the prospects for future demand growth. Overall, the study makes a contribution to the modeling, based on limited data, of grain demand in a transition economy.

The study is limited by data availability. More accurate price data and more detailed consumption data, based on household surveys, would enable estimation of more detailed and comprehensive demand systems. The estimation of feed grain demand is indirect due to the limitations of data on feed grain usage. The approach of the study requires accurate predictions of meat consumption and accuracy in the grain-meat conversion ratios that are used. There are also complaints about discrepancies in China's statistical data on meat (Tian et al. 1999) and there is little research that has focused on the grain-meat conversion ratio. These problems may affect the accuracy of the estimation results.

Dairy consumption is not considered in this study, which might add to the feed grain demand prediction. Despite its recent rapid expansion, dairy is still a small sector in China. Cows are generally fed on grass and other coarse grains (mainly corn). The expansion of the dairy sector could increase the demand for corn in China. Canada is not a major corn producing/exporting country, so rapid expansion of China's dairy sector is not likely to influence feedgrain trade between Canada and China dramatically in the near future.

Another limitation of this research is that the supply side is not directly estimated. The supply side estimation is static and non-interactive with changes in demand. A partial equilibrium model might provide a sounder approach if data for this were available. Overall, the major limitation of this study and other research on China's demand for meat and feed grain demand, and the major recommendation relating to future analysis, hinges on the quality and availability of data.

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APPENDICES

Appendix 1 Definitions of Grain

The **State Statistical Bureau (SSB) of China** defines “grain” as cereals, beans, tubers and others (like buckwheat). Cereals include wheat, rice, corn, and other major coarse grains (sorghum, millet, barley and oats, etc.) exclude oilseeds. Rice is in paddy form and potatoes are converted to grain by the ratio of 5:1 since the year 1964 (before 1963, the conversion ratio is 4:1. Data on total grain and potato production prior to 1964 have been adjusted to a consistent 5:1 dry weight grain basis in this study). The definition of grain by SSB can be expressed as:

Grain = Cereals + Beans + Tubers+ Others

Wheat, rice and corn account more than 95% of total cereal output and 85% of grain output. Tuber crops supplied as vegetables in cities and suburbs are calculated as fresh products (such as potatoes) instead of grain. Output of all other grains refers to husked grain.

The **Food and Agriculture Organization of United Nations (FAO)** definition of grain covers paddy rice, wheat, maize and other coarse grains but with rice converted into a milled form using an average conversion ratio of 65%. The time reference for statistics on productions of crops is based on the calendar year. Totally 17 cereals are included, like wheat, paddy rice, maize, barley rye, oats, millet, sorghum and mixed grain etc. In the FAO concept, cereals refer to crops harvested for dry grain only. Crops harvested green for forage, silage or grazing is classified as fodder crops. Also excluded are industrial crops, e.g. broom sorghum (Crude organic materials) and sweet sorghum when grown for syrup (Sugar crops). For international trade classifications, fresh cereals (other than sweet corn), whether or not suitable for use as fresh vegetables, are classified as cereals.

The **United States Department of Agriculture (USDA)** definition of grain includes wheat, rice (measured in milled form), and coarse grain. The major grains (rice, wheat, corn, sorghum, and millet) are calculated on a dry, rough (unprocessed, unmilled, or unhusked) weight basis. The statistics used in USDA are collected by the "world" production year beginning July 1st of the year indicated. Coarse grains include corn, barley, sorghum, oats, rye, millet and mixed grains.

Appendix 2 Different Sources of China's Official Data

The State Statistical Bureau (**SSB**) publishes China's Statistical Yearbook every year to the world, which covers very comprehensive data series for the year and some selected historical important years and the most recent ten years at national level and local levels of province, autonomous region, and cities directly under central government and therefore, reflects various aspects of China's social and economic development. That is the main data sources for foreign countries to access China's official data. The major data sources of the publication are annual statistical reports, and some from sampling surveys done by SSB.

China's Ministry of Commerce (**MOC**) publishes the China's Commerce Yearbook, which is the only source for many of the procurement and consumption statistics. The MOC is also the only source for provincial-level grain procurement and sales data broken down by fixed and negotiated price. And finally, the MOC is the data source for total national, urban, and rural consumption of certain agricultural commodities. The MOC has its own internal statistical system to collect and process data published in its yearbook. Most SSB data are consistent with MOC.

China's Ministry of Agriculture (**MOA**) publishes China's Agriculture Yearbook. The data follows closely with China's Statistical Yearbook, Agriculture Party. MOA production and area data are collected by a somewhat different statistical system. Therefore, there are occasions where there are more significant differences between the data reported by SSB and MOA. The MOA also conduct household survey and publishes the household survey data in its yearbook. But sample sizes are extremely small, and it is unknown whether or not the sample selection was random. As with any other survey, the accuracy of the survey depends on how representative the sample is and how clearly and consistently definitions, such as standard labour days, are applied. The meaning and consistency of definitions, both within and between crops, are also unknown. It is also unclear how the survey methodology may have changed following the dissolution of the commune system and the introduction of the household responsibility system (HPRS). The SSB's China Rural Statistics Yearbook provides national-level cost-of- production data. However, the yields used by the SSB do not correspond with the yields used by MOA, making the cost-per-yield data inconsistent. Furthermore, the MOA provides only provincial-level data, whereas the SSB provides only national-level data.

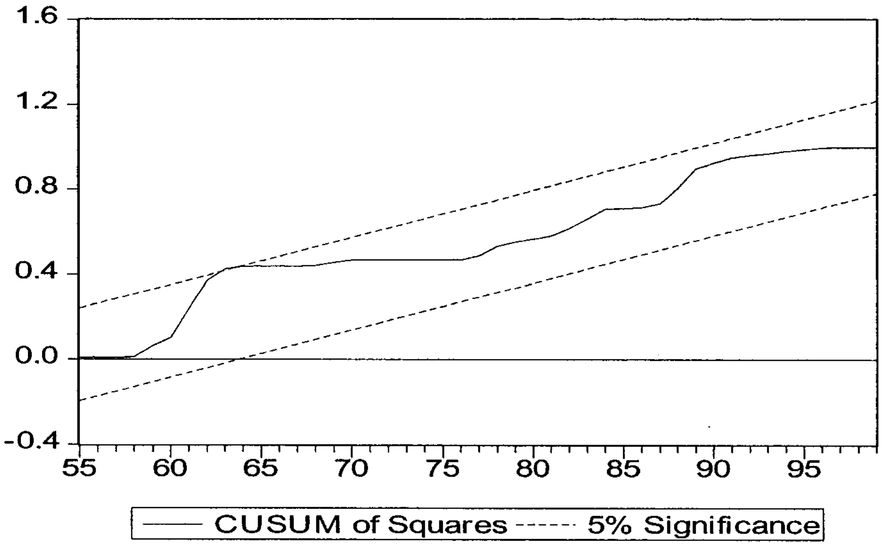
There are two official sources for trade statistics in China: China's Customs Administration (**Customs**) and the Ministry of Foreign Economic Relations and Trade (**MOFERT**). Volume and value statistics are from Customs, but historical data are from MOFERT statistics. These are very consistent with the data in the part of China's Statistical Yearbook on Foreign Economy Trade and International Tourism.

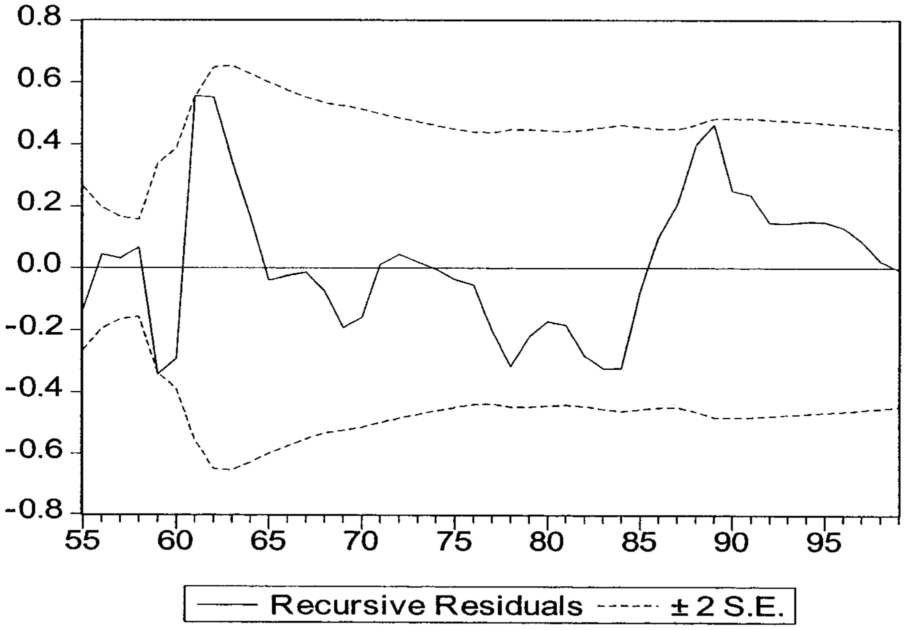
Appendix 3 Grain Policy Changes and Major Events After 1978

Year	Grain Policy
1978	Household Responsibility System was adopt in rural area of China
1988-89	The central government severely restricted the trading of rice
1991	Establishment of wholesale markets
1991	Deng Xiaoping's Famous trip to the south in 1991 encouraged local leaders to specialize even further.
1992-93	Fully liberalized grain market trade by eliminating planned price procurement and sales of grain, and opening up trade in rural and urban market.
1993	Establishment of future markets
1993-94	The government adopted a Governor Responsibility System (GRS), which made provincial governors responsible for safe guarding the food needs of their citizens
1998	"New Policy" Documented by "Liangshi Shougou Tiaoli (grain procurement ordinance)", passed by the State Council on June 1, 1998.

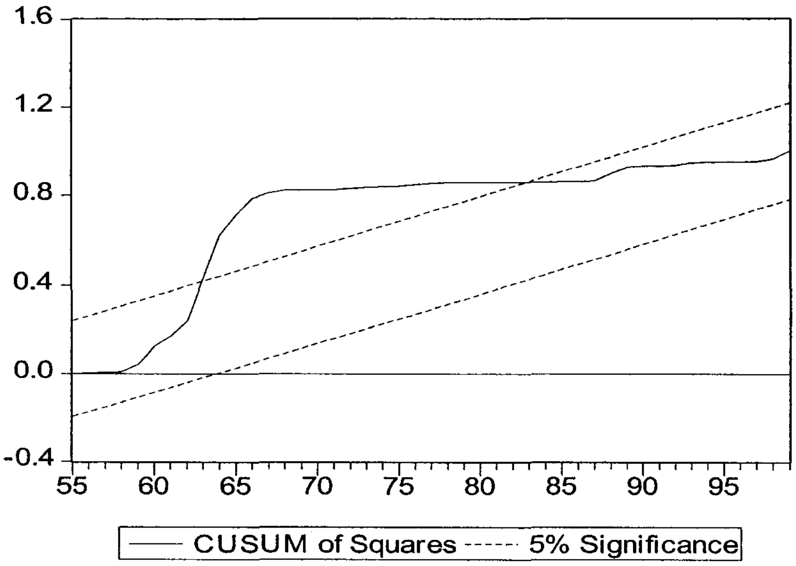
Appendix 4 Recursive Residuals and CUSUMSQ Tests: Meat and Spirits.

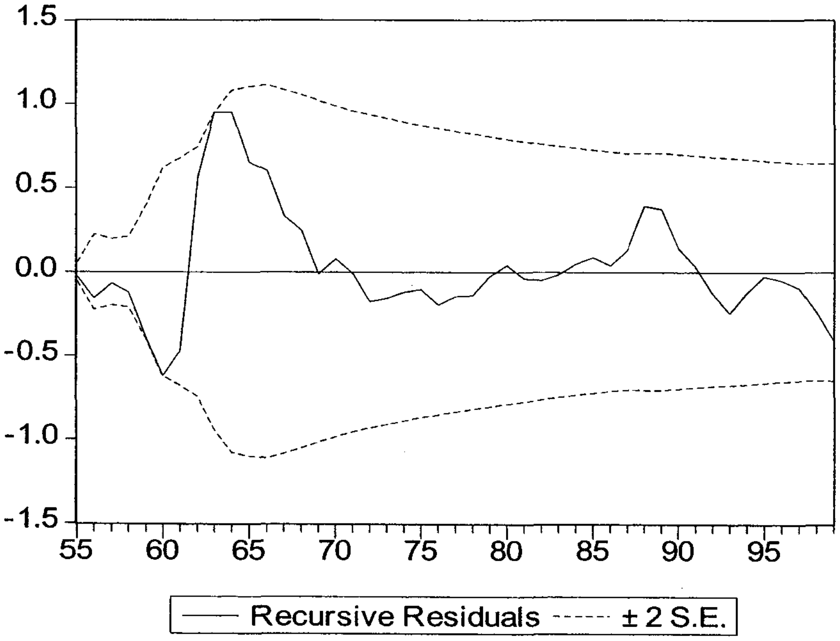
Rural Meat Consumption: CUSUMSQ Test and Recursive Residuals



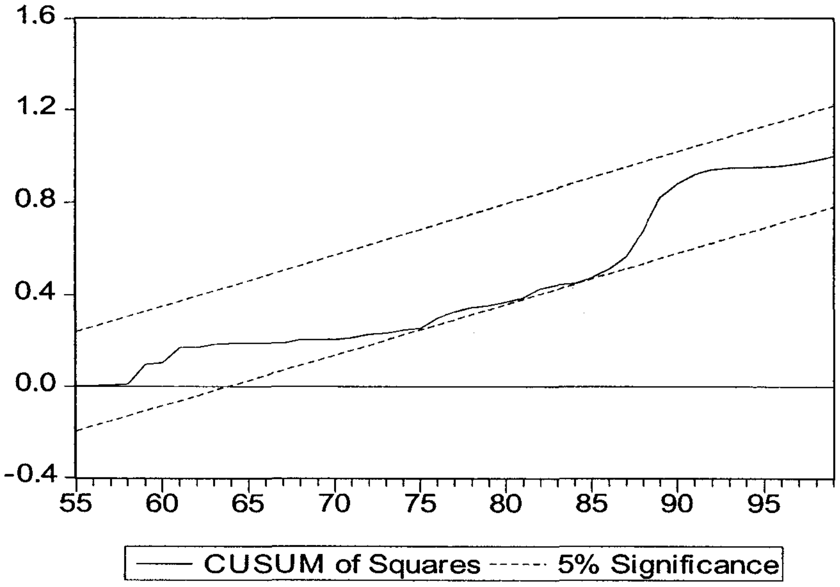


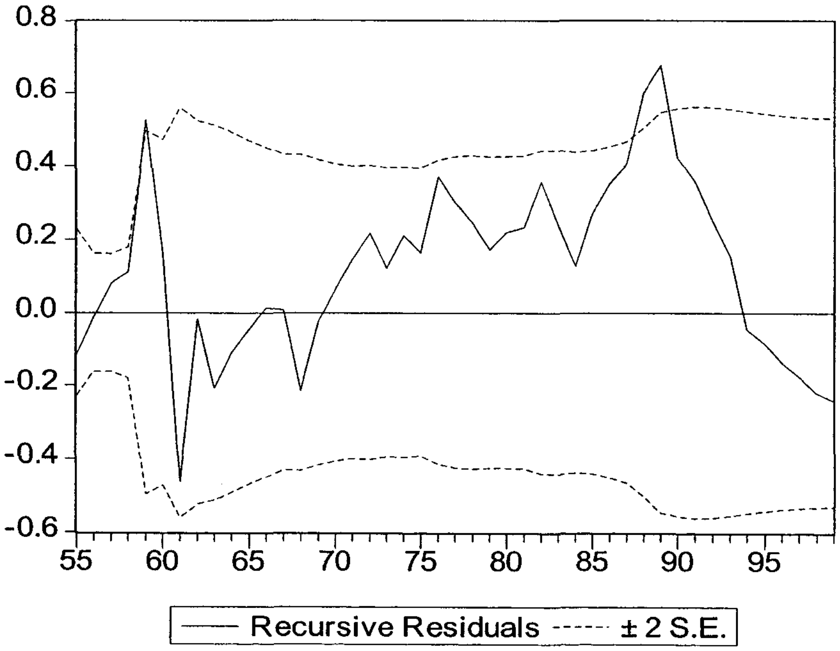
Urban Meat Consumption: CUSUMSQ Test and Recursive Residuals



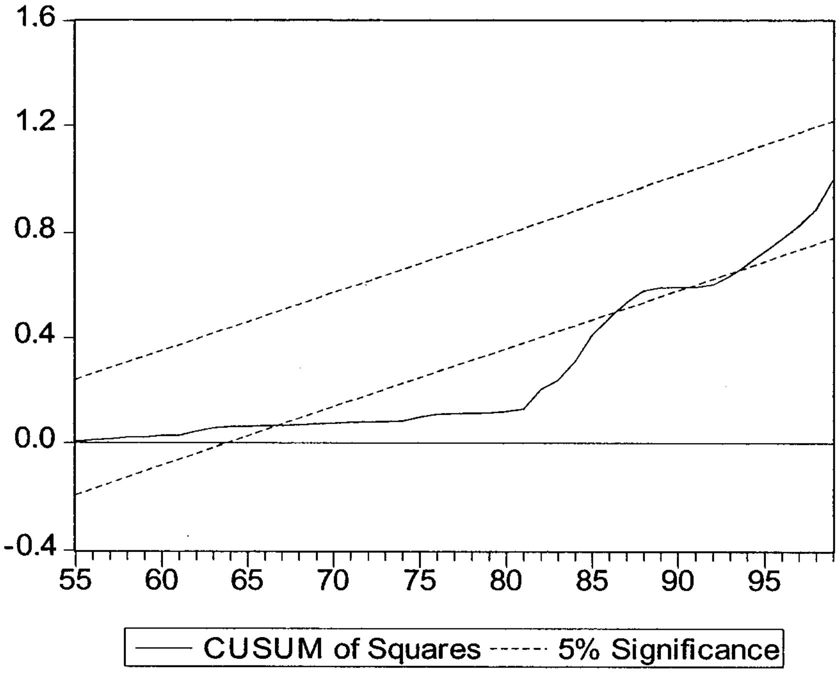


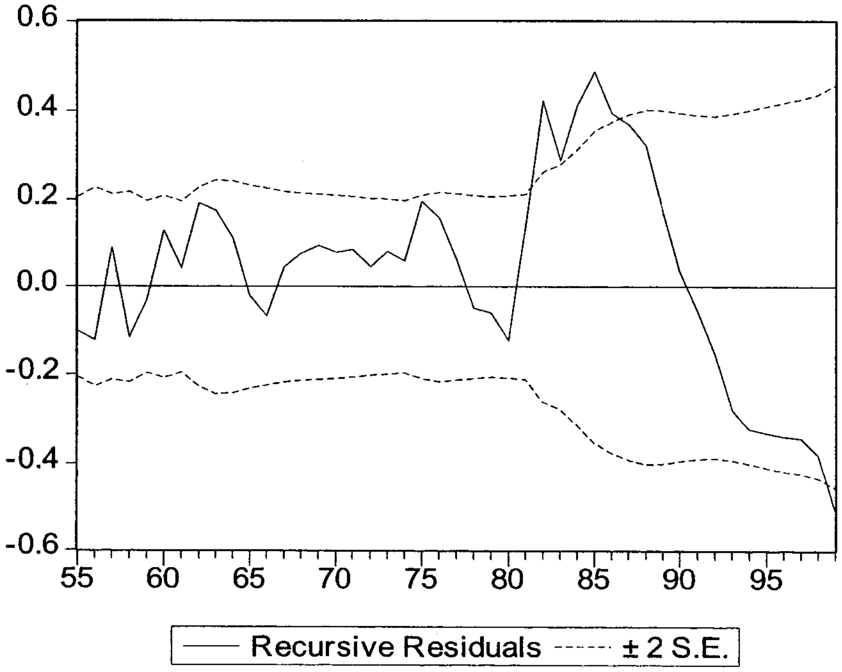
Rural Spirits Consumption: CUSUMSQ Test and Recursive Residuals





Urban Spirits Consumption: CUSUMSQ Test and Recursive Residuals





Appendix 5 China's Grain Production, Consumption and Trade

1. Grain Consumption and Feed Grain Demand

In China, there are four components of grain demand: grain that is directly consumed as food; feed grain that is fed to animals and consumed indirectly; grain that is used in non-food manufacturing purposes, such as spirits; and other grain consumption, like seed and waste. Direct consumption is by far the largest component of grain utilisation, accounting for more than 65% of total grain production during the period from 1998 to 2001. Feed is the second largest component of grain utilisation, claiming about 25% of production. Non-food manufacturing and seed usage ranked third and fourth in terms of grain utilisation, at about 2.7% and 2.4% of total grain production during the cited period (Table A-1).

The aggregation of grain balances gives the utilisation of rice, wheat, and maize in terms of the use of grain for feed and food and rural-urban dietary habits (Table A-1 rows 2-5). About 89% of the nation's total rice supplies, and 88% of wheat supplies, are consumed directly as food grain. Some 67% of China's maize supply is used as feed for the livestock sector.

On a per capita basis, the average resident in urban areas of China consumed 101 kilograms of grain per year in 2001, while a typical the average rural resident consumed 238 kilograms of grain. On average, per capita grain consumption in China in 2001 was 190 kilograms (weighted average of urban and rural per capita consumption, SSB, 2001). This level of direct grain consumption is still quite high in comparison to the rest of East Asia. Average per capita red meat consumption was 19 kilograms and 15 kilogram for urban and rural residents respectively; and per capita fish consumption was 10 and 4 kilograms respectively for urban and rural residents in 2001 (FAO, 2004).

With economic growth and future development, direct food grain consumption can be expected to gradually be reduced, with dietary changes. The demand for feed grain can be expected to rise as a result of increasing animal protein consumption. This trend is clearly shown in Table A-2, which summarizes per capita cereal and meat consumption in the past four decades, from 1969 to 2001.

Per capita cereal consumption increased from 152 kilograms per capita in the 1970s to 205 kilograms per capita in the 1990s, and then fell to 182 kilograms in the 2000s. Fine grain consumption, wheat and rice, reached a plateau in the 1990s and then start to decrease. Coarse grain consumption, maize for example, reached a consumption peak in the early 1980s and has decreased rapidly since then. Per capita consumption of red meat, poultry and fish has increased rapidly and continuously since the early 1980s. The average per capita consumption level of red meat in the period from 1969 to 1971 averaged only 8 kilograms per capita; however, in the period from 1999 to 2001, meat consumption averaged 39 kilograms per capita, almost five times the level in the early 1970s. Average per capita fish consumption during 1999 to 2001 increased five times, compared with the average in 1969 to 1971. Average per capita poultry consumption in the period from 1969 to1971 was only 1 kilogram; by the period from 1999 to 2001, the average reached 10 kilograms, 10 times the level of three decades ago.

Table A-2 clearly shows that dietary changes are ongoing in China. It can be expected that many of these trends will continue, leading to the question of how rapidly will this continue in the future. Since China, has one fifth of the world's population and 7% of the world's land, the influence on the world grain market is of much interest. To have a clearer picture of China's dietary status, we compare China's diet structure with that in other East Asian countries in Table A-3. Table A-4 compares per capita consumption of animal products and their shares in the total diet, in energy terms, in selected Asian countries during the past three decades. The share of animal products in the total diet in China in thousand calories per capita per day is already higher than in Korea, Malaysia and other eastern Asia countries, and is second only to Japan in the period from 1998 to 2001.

Table A-1 Annual Average Grain Production, Utilization and Per Capita Food Consumption in China: 1998 to 2001

						Disposal of available supply					Per capita food consumption in 2001 (kg)		
		Production	Change in Stock	Net import	Total supply	Seed	Animal feed	Non-food manufacturing	Waste	Food	Average	Urban	Rural
Total grain		368	3	1	372	9	92	10	21	237	190	101	238
	Wheat	108	0	2	110	4	4	1	4	97			
	Rice	130	0	-2	128	3	3	1	6	114			
	Other grain	13	0	2	15	0	0	4	1	5			
	Maize	117	3	-1	119	2	80	3	10	21			
Red meat										48	20	19	15
Pork										41	14	16	13
Poultry										12	4	5	3
Fish										31	6	10	4

Source—Computed from FAO FAOSTAT database, 2004.

Note—1. All values are in million tons, except for per capita food consumption which is in kilograms and apply to year 2001. The other data are the averages for 1998 to 2001. Rice is in milled form (trade weight).

2. A negative number indicates a decrease in stocks, which implies decreased total grain supply.

3. Food includes direct home consumption, grain purchased and consumed outside of home, and processed foods

Table A-2 Per Capita Food and Meat Consumption, China, Selected Periods
Unit: kilograms

Year	Cereal				Red Meat	Poultry	Fish, sea Food
	Total	Wheat	Rice	Maize			
1969-71	152	33	76	20	8	1	5
1979-81	187	61	86	26	13	2	5
1989-91	205	81	94	23	22	3	11
1999-01	182	75	89	15	39	10	25

Source—Computed from FAO FAOSTAT database, 2004.
Note—All values are in kilograms, only home consumption is included. Rice is in milled form (trade weight).

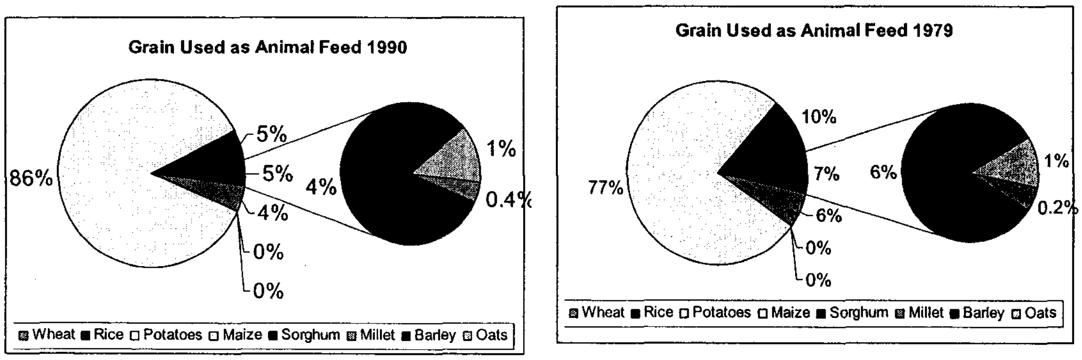
Total meat production increased by 17 million metric tons in 2001 compared to the total output in 1996. If the average feed to meat conversion ratio was 4 or 5 to 1, the total feed grain demand should have increased by around 70 to 80 million metric tons during this period. The increased feed demand was not supported by imports, nor by increased domestic production. Instead, China's total grain production decreased by 45 million metric tons in 2001, compared to the output level in 1996. China was a net grain export country from 1996 to 2001 (Figure 1-1). How could China fill the apparent "gap" of 120 million metric tons of grain while satisfying increasing domestic grain consumption?

There is an argument that China's meat production data reports have been over-estimated (Ma et al, 2002; Colby et al, 1999; Fuller et al, 1999; Aubert, 1999). This might explain part, but not all of the reason, since meat consumption data also showed the same upward trend as supply data. We believe that more attention should be paid to the modes of technology in China's meat production to understand grain use and demand.

The direct evidence that underlies the pattern of consumption is that coarse grain used for animal feeds more than quadrupled between 1979 and 2000, from 21.8 million metric tones to 94.9 million metric tones. When wheat is included, grain use increased from 23.3 million metric tones to 96.9 million metric tones (Table A-4). Pigs and poultry are the two livestock classes that consume most feed grain. Pork and poultry meat account for more than 90% of total meat output and consumption in China (SSB, 2002).

Figure A-1 indicates the composition of animal feed in 1979 and 1990 (the last year for which more complete data is available). One big difference between the two years is that the weight of maize in total feed increased appreciably, from 77% in 1979 to 86% in 1990. Wheat accounts for around 4-6% and other coarse grain about 10-16% of livestock feed. Among other coarse grains, barley used as feed grain has increased from 4% in 1979 to 6% in 1990; sorghum weight dropped from 10% in 1979 to 5% in 1990. In absolute value terms, barley used as feed grain has increased from 1.4 million metric tons in 1979 to 2.3 million metric tons in 1990.

Figure A-1 Composition of Feed Grain in 1979 and 1990, China



Source: USDA/ERS Data.

Statistics are not available, for example, on the use of rice and potatoes, "...but unofficial estimates are that about 20 million metric tones of rice and 15 million metric tones of potatoes were fed in 1990. If so, about 15 percent of rice and 50 percent of potato production is fed to livestock." (Simpson et al. 1994, p297) There has been a substantial increase in the proportion of all coarse grains fed to livestock since the early 1980s as a result of human diet improvement due to income growth.

China has a long history of utilizing nonconventional feed resources (NCFR), including crop residues, by-products and garbage in suburban areas as

Table A-3 Per Capita Consumption of Animal Products and Their Shares of Total Diet in Energy Terms, China, Selected Periods

Country	Animal Product (Kcal/Capita/Day)				All Food (Kcal/Capita/Day)				Share of Animal Product as % Share of All Food			
	1968-72	1978-82	1988-92	1998-01	1968-72	1978-82	1988-92	1998-01	1968-72	1978-82	1988-92	1998-01
China	127	172	313	572	1998	2364	2668	2975	6	7	12	19
Indonesia	54	69	103	121	2025	2414	2664	2892	3	3	4	4
Japan	419	527	615	561	2685	2754	2888	2751	16	19	21	20
Malaysia	285	400	446	529	2467	2691	2767	2915	12	15	16	18
Republic of Korea	121	258	407	438	2814	3127	3278	3028	4	8	12	14
Thailand	208	203	231	289	2183	2221	2361	2463	10	9	10	12

Source—Computed from FAO FAOSTAT database, 2004.
Note—All values are in thousand calories per capita per day.

Table A-4 Grain Used for Animal Feeds, China, 1979-00

				Coarse grains							
Year	Whea	Ric	Potatoe	Maiz	Sorghu	Mille	Barle	Oat	Total	Ry	Total
	---1,000,000 tonnes---										
1979	1.5	n.a.	n.a.	17.8	2.3	0.1	1.4	0.2	21.8	n.a	23.3
1980	1.6	n.a.	n.a.	26.1	2.8	0.1	1.8	0.3	31.1	n.a	32.7
1985	2.3	n.a.	n.a.	43.2	3.8	0.2	2.6	0.4	50.2	n.a	52.5
1990	2.7	n.a.	n.a.	52.9	3.3	0.1	2.3	0.4	59.0	n.a	61.7
1991	5.0	n.a.	n.a.	54.5	n.a.	n.a.	n.a.	n.a.	58.0	n.a	63.0
1992	2.8	n.a.	n.a.	60.0	n.a.	n.a.	n.a.	n.a.	63.4	n.a	66.1
1993	2.7	n.a.	n.a.	65.5	n.a.	n.a.	n.a.	n.a.	69.7	n.a	72.4
1994	3.0	n.a.	n.a.	74.0	n.a.	n.a.	n.a.	n.a.	79.6	n.a	82.6
1995	3.2	n.a.	n.a.	78.0	n.a.	n.a.	n.a.	n.a.	81.4	n.a	84.6
1996	3.4	n.a.	n.a.	82.0	n.a.	n.a.	n.a.	n.a.	85.6	n.a	89.0
1997	4.9	n.a.	n.a.	86.0	n.a.	n.a.	n.a.	n.a.	88.9	n.a	93.8
1998	5.0	n.a.	n.a.	87.0	n.a.	n.a.	n.a.	n.a.	90.4	n.a	95.4
1999	6.5	n.a.	n.a.	90.0	n.a.	n.a.	n.a.	n.a.	93.2	n.a	99.7
2000	8.0	n.a.	n.a.	93.0	n.a.	n.a.	n.a.	n.a.	95.4	n.a	103.4
	---Percent---										
1979	6.4	0.0	0.0	76.4	9.9	0.4	6.0	0.9	93.6	0.0	100.0
1980	4.9	0.0	0.0	79.8	8.6	0.3	5.5	0.9	95.1	0.0	100.0
1985	4.4	0.0	0.0	82.3	7.2	0.4	5.0	0.8	95.6	0.0	100.0
1990	4.4	0.0	0.0	85.7	5.3	0.2	3.7	0.6	95.6	0.0	100.0
1991	7.9	0.0	0.0	86.5	0.0	0.0	0.0	0.0	92.1	0.0	100.0
1992	4.2	0.0	0.0	90.8	0.0	0.0	0.0	0.0	95.9	0.0	100.0
1993	3.7	0.0	0.0	90.5	0.0	0.0	0.0	0.0	96.3	0.0	100.0
1994	3.6	0.0	0.0	89.6	0.0	0.0	0.0	0.0	96.4	0.0	100.0
1995	3.8	0.0	0.0	92.2	0.0	0.0	0.0	0.0	96.2	0.0	100.0
1996	3.8	0.0	0.0	92.1	0.0	0.0	0.0	0.0	96.2	0.0	100.0
1997	5.2	0.0	0.0	91.7	0.0	0.0	0.0	0.0	94.8	0.0	100.0
1998	5.2	0.0	0.0	91.2	0.0	0.0	0.0	0.0	94.8	0.0	100.0
1999	6.5	0.0	0.0	90.3	0.0	0.0	0.0	0.0	93.5	0.0	100.0
2000	7.7	0.0	0.0	89.9	0.0	0.0	0.0	0.0	92.3	0.0	100.0

Source: Data before 1990 are from USDA/ERS, Asia and Pacific Rim Branch, official unpublished statistics; Data after 1990 are from USDA/ERS, various issues.

livestock feeds. As animal feeding has modernized, the proportion of use of such feedstuffs has diminished, but to what extent is still an open question. The NCFRs continue to play an important role in current livestock production. This makes China's feed practices different from many other countries. Most feed grain demand research has ignored this, in part due to the difficulty of tracing the use of NCFRs accurately. This has led to overestimation of the demand for feed grains.

2. Grain and Feed Grain Production

China's grain production increased very rapidly after the 1978 policy reform benchmarked by the Household Responsibility System (HRS). Grain production reached an historical high of 349 kg/capita in 1982. For the next decade, the output stabilized around 310-350 kg/capita. Although grain yields continued to grow, output was absorbed by a continually enlarged population (Table A-5). The level of per capita grain output did not exceed 350kg/capita until 1996. Successive years of good weather and changing policy brought China's grain production in new historical highs in the late 1990s.

Severe extensive dry weather in 1999 pulled the output down by more than 10% annually in the next two years. The per capita output dropped to the historical low of 273kg/capita in 2000, even lower than the level of 1978. USDA data indicate that production further decreased in 2003 to 324 million metric tons or only 287kg/capita (USDA, 2003; CPIRC, 2004).

Feeding of grain to livestock in China has increasing replaced human consumption of coarse grains; corn, and other coarse grains used to be components of Chinese diet, especially in northern China. This situation has changed much since the 1980s because personal income has rapidly increased and harvests rose sharply in the 1990s. Fine grain (wheat and rice) are the major components of the Chinese diet (Carter and Zhong, 1999). Coarse grains are more used as feedgrain due to the diet improvement. Feeding grain to livestock occurs especially in large commercial operations and this involves mostly coarse grain and low quality food grain (i.e. low quality wheat and rice). "Specialized households rely far less on home-grown grain and farm by-products, and are more responsive to grain prices than traditional 'backyard' operators" (Fang et al. 2000, p24). The proportion of national coarse grain production used for animal feed is increasing (Table A-6).

The share of total grain production used for animal feed is increasing slowly but steadily and is approaching around one third of the total grain output (last column, Table A-6). Nevertheless, the share of course grains used for feed has

Table A-5 China's Grain Production and Population: 1984-2000

Year	Output (million metric tons)	Pop (billion)	Per capita output (kg/capita)
1978	305	0.96	317
1979	332	0.98	341
1980	321	0.99	325
1981	325	1.00	325
1982	355	1.02	349
1983	339	1.03	330
1984	360	1.04	346
1985	334	1.06	316
1986	347	1.08	323
1987	353	1.09	323
1988	347	1.11	312
1989	364	1.13	323
1990	400	1.14	350
1991	392	1.16	339
1992	397	1.17	339
1993	401	1.19	339
1994	390	1.20	325
1995	412	1.21	340
1996	447	1.22	365
1997	439	1.24	355
1998	453	1.25	363
1999	390	1.26	310
2000	345	1.27	273
[1]1978-84	2.79%	1.28%	1.50%
1985-00	0.22%	1.20%	-0.97%
1978-00	0.57%	1.25%	-0.68%

Source: Output data are from USDA/ERS, population data are from China's Statistical Year Book (Various Issues); Note—1. Calculated annual compound rate of increase

trebled since 1979. It is evident that upgrading of peoples' diets has released coarse grain from direct food consumption, making this available for feed usage. We note until the late 1970s, coarse grains and potatoes had accounted for a large proportion of total food grain consumption in China's rural areas: "In 1978, for example, the consumption of coarse grain (including potatoes) in the rural areas accounted for 50.4 percent of total direct grain consumption" (Dong et al, 1995, pp: 327). By 1985, the consumption of coarse grain in the rural areas accounted for only 19% of total direct grain consumption (SSB, various issues).

Table A-6 Grain Production Used for Animal Feeds, China, 1979-2003
Unit: percentage

				Coarse grains							
Year	Whe	Ric	Potatoes	Maize	Sorghum	Millet	Barley	Oats	Total	Rye	Total
	Percent										
1979	2	0.0	0.0	30	30	2	18	24	26	N.A	16
1985	3	0.0	0.0	68	68	3	42	60	61	N.A.	31
1990	3	0.0	0.0	54	58	2	40	59	51	N.A.	29
1991	5	0.0	0.0	55	N.A.	N.A.	N.A.	N.A.	52	N.A.	16
1992	3	0.0	0.0	55	N.A.	N.A.	N.A.	N.A.	58	N.A.	17
1993	3	0.0	0.0	63	N.A.	N.A.	N.A.	N.A.	59	N.A.	18
1994	3	0.0	0.0	64	N.A.	N.A.	N.A.	N.A.	70	N.A.	21
1995	3	0.0	0.0	75	N.A.	N.A.	N.A.	N.A.	65	N.A.	21
1996	3	0.0	0.0	70	N.A.	N.A.	N.A.	N.A.	61	N.A.	20
1997	4	0.0	0.0	64	N.A.	N.A.	N.A.	N.A.	78	N.A.	21
1998	5	0.0	0.0	82	0.0	0.0	0.0	0.0	63	N.A.	21
1999	6	0.0	0.0	65	0.0	0.0	0.0	0.0	68	N.A.	26
2000	8	0.0	0.0	70	0.0	0.0	0.0	0.0	84	N.A.	30
2001	9	0.0	0.0	89	0.0	0.0	0.0	0.0	91	N.A.	27
2002	6	0.0	0.0	90	0.0	0.0	0.0	0.0	94	N.A.	27
2003	6	0.0	0.0	93	0.0	0.0	0.0	0.0	94	N.A.	27

Source: Data before 1990 are from USDA/ERS, Asia and Pacific Rim Branch, official unpublished statistics presented by Simpson, 1994, Table 10.2. Data after 1990 are computed from USDA/ERS, World Grain Market: Production and Trade, 2001.

Another reason for the increase of the proportion of coarse grain in total feed grain is that yields of fine grains (rice and wheat), especially rice, have increased appreciably during the last several decades (SSB, 2002). The output of maize, a major coarse grain, has also increased. but other coarse grains, specifically millet and sorghum, have decreased in both sown area and yield (SSB, 2002). In sum, overall, the production and use of feed grain has increased considerably over time in China (Table A-6).

3. Grain and Feed Grain Trade

China was a major grain exporter several decades ago. During the period from 1950 to 1960, China exported a total of 25 million metric tons of unprocessed grain, an annual average of 2.77 million metric tons. China became an net grain importer in the late 1970s and remained so until the mid 1990s. Annual import demand has varied from 3 to 17 million metric tons (Figure 1-1). Nonetheless, China was also an exporter of rice and maize, increasingly so after late 1990s.

Before the 1970s, wheat was the only major grain imported by China from the international market. In the last ten years, the share of wheat imports dropped to less than 50% of total grain imports; in 1999/00, the share of wheat in grain imports was less than 21%. However, coarse grain import volumes have rapidly grown recently and have overtaken the import share of wheat since 1998. The share of import volumes for coarse grain reached a high of 75.5% in 1999. Barley is the major coarse grain that China has imported in recent years. In 1980, only 0.1% of world barley exports were shipped to China, but in 1999, China's barley import share increased to 11%, 110 times that of twenty years before. However, barley is used mainly in the brewing industry in China, rather than as a livestock feed. Maize is the major grain for animal feed in China and imports have increased in recent years, although these amounts are less than 10% of China's total grain imports. As mentioned previously, more than 80% of maize use in China is as feed for the livestock sector. Maize is still China's major grain export product, accounting for more than 70% of China's total grain export in volumes. The composition of grain imports was mainly wheat in earlier years and has become more diverse over time (Table A-7).

Table A-8 summarizes relationships among grain yield, output, import/export and ending stocks. The harvested area of wheat decreased from 30 thousand hectares in 1998/99 to 22 hectares in 2000/01. The harvested area of corn decreased from 25 hectares in 1998/99 to 23 hectares in 2003/04. The decrease in harvested area caused a decrease in total grain production. In 2003/04, total grain production was 322 million metric tons, more than 100 million metric ton less than the production level of 453 million metric tons in 1998/99.

Some economists have concluded that dietary improvements of China's population will lead to a major shift in grain imports from wheat to feed grain (Carter and Zhong, 1988, 1991; Anderson (1), 1990; Fuller et al, 1999; Huang, Rozelle, and Rosegrant, 1999; Huang and Rozelle, 2003). Other researchers have questioned the pace of this adjustment: "What we have observed instead is that China's grain exports have shifted substantially from rice to coarse grain since 1978, but the marginal status of coarse grain in China's total grain imports has, by and large, stayed the same." (Dong, et al. 1995, p326). From 1984/85 to 1990/91, China's sales of coarse grain in world markets averaged 5.2 million tons each year, accounting for 6.4% of total world coarse grain exports. Meanwhile, the share of coarse grain in total import volume increased from 8.6% during 1961/62-1971/77 to 12% in the period from 1977/78 to 1983/84, then was 7.0% from 1984/85 to 1990/91. In the period from 1984/85 to 1990/91, China's average annual imports of coarse grain did not exceed one million tons. Even more striking, as exports of coarse grain grew, the share of coarse grain in China's domestic cereal production continued to fall slowly, while the proportion of rice production rose gradually. The evidence, at least until 1999, suggested the upgrading of direct cereal food consumption had overridden increased animal protein consumption as the major force in the adjustment of China's cereal production and trade. Dong et al (1995, p337) concluded:

> *"Animal protein consumption will experience steady growth; yet emphasis can be expected to be on increased consumption of commodities such as poultry and egg which have a low rate of grain-protein conversion. As a result, pressure on feed grain demand from a rapid growth in national income is expected to be moderate. China's demand for wheat and rice imports is expected to continue to increase, while its coarse grain exports may fall gradually. "*

Consequently, it was argued that a dramatic shift in China's cereal imports from wheat to feed grain was unlikely to occur in the immediate future.

As events unfolded in the early 2000s, China's expanded grain production has negated the need for much wheat importation in the short run while the moderate levels of coarse grain imports that are occurring are largely for brewing, not for feed grain use. However, recent data from USDA also show that feed grain demand has increased at a rapid rate, from a low base. During the period from 1985 to 2003, the demand for corn as feed grain more than doubled, from 43.2 million metric tons to 94 million metric tons, an annual growth rate of 8.54%, although corn exports increased to around 10 million metric tons in recent years.

Table A-7 China: Grain Supply and Demand, Wheat, Corn and Rice, 1998/99 to 2003/04 Unit: million metric tons (MMT)/hectares

MMT	Area		Production	Imports	Exports	Domestic	Domestic	Ending
	Harvested	Yield				Feed Use	Total Use	Stocks
Wheat								
1998/99	30	4	110	1	0	5	108	98
1999/00	29	4	114	1	1	7	109	103
2000/01	27	4	100	0	1	10	110	92
2001/02	25	4	94	1	2	9	109	77
2002/03	24	4	90	0	2	7	105	60
2003/04	22	4	86	2	2	6	105	42
Corn								
1998/99	25	5	133	0	3	87	116	104
1999/00	26	5	128	0	10	90	118	104
2000/01	23	5	106	0	7	91	120	83
2001/02	24	5	114	0	9	92	123	65
2002/03	25	5	121	0	15	93	127	44
2003/04	24	5	114	0	8	94	129	21
Rice								
1998/99			139	0	4	134	96	0
1999/00			139	0	3	134	99	0
2000/01			132	0	3	134	94	0
2001/02			124	0	2	135	82	0
2002/03			122	0	2	135	67	0
2003/04			115	0	3	135	49	0
Grain								
1998/99	59	4	392	4	8	97	371	202
1999/00	58	4	390	4	13	100	373	207
2000/01	53	4	345	3	11	103	375	175
2001/02	52	4	340	3	12	103	376	142
2002/03	52	4	342	3	19	102	377	106
2003/04	49	4	322	4	11	103	378	64

Source: Computed from USDA/ERS database.

Table A-8 Grain Import Composition 1966-70 and 1996-2000 Unit: thousand metric tons (,000) and percentage

Year	Grain (,000)	Wheat (%)	Rice (%)	Corn (%)	Coarse Grain (%)	Year	Grain (,000)	Wheat (%)	Rice (%)	Corn (%)	Coarse Grain (%)
1966/67	6440	96	0	0	0	1999/00	3578	28	5	3	64
1967/68	4700	93	0	0	0	2000/01	2878	7	10	3	80
1968/69	4600	97	0	0	0	2001/02	3367	33	8	0	59
1969/70	3790	99	0	0	0	2002/03	2505	16	12	0	72
1970/71	5360	99	0	0	0	2003/04	3800	53	7	3	37

Source: Computed from USDA/ERS database.

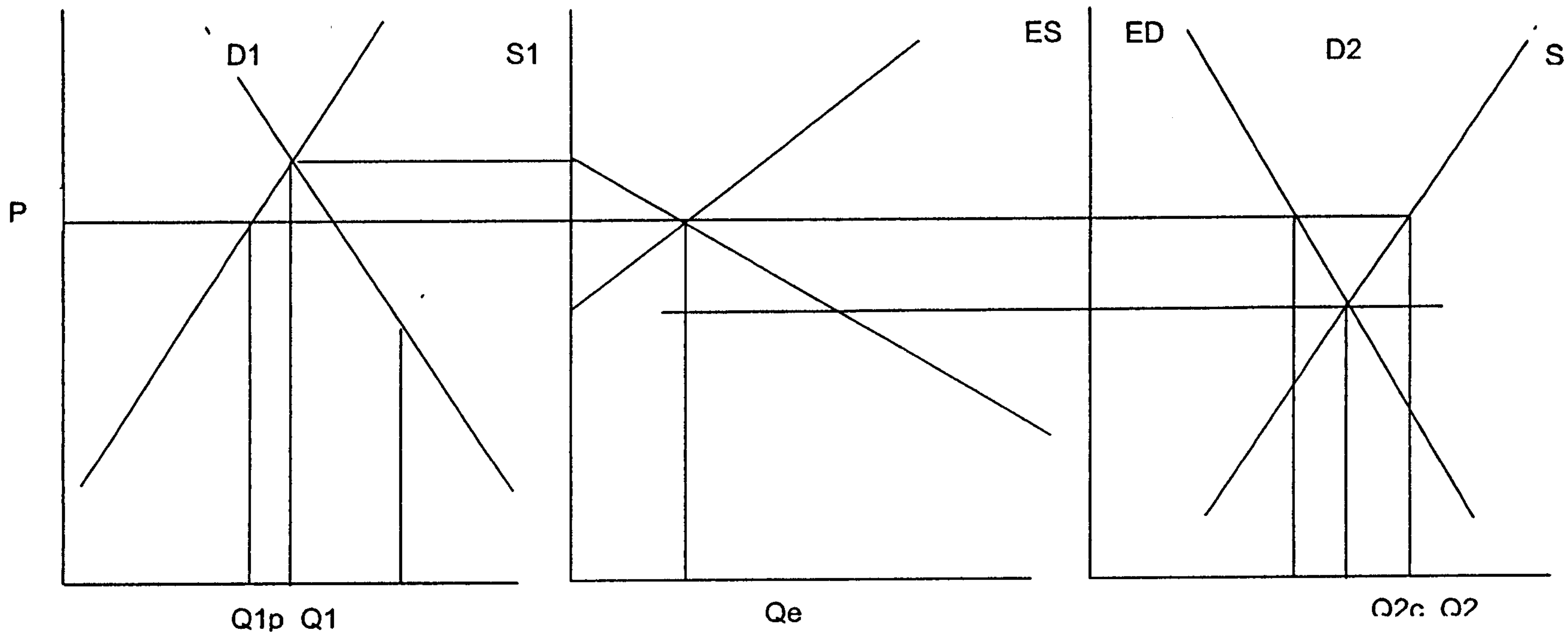
Table 4-3: *Time-varying Parameter Estimates of Rural and Urban Grain Demand*

Sample: 1953-1999
Included Observation: 41

	Rural Grain		Urban Grain		Rural Meat		Urban Meat		Rural Spirit		Urban Spirit	
	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.	Coef.	Std. Err.
C_0	5.1718***	0.0005	-1.1422***	0.3625	-1.0403***	2E-05	-3.9860***	0.0002	-3.4354***	1.2433	-0.2615	0.9550
$\overline{C_p}$	-0.0366***	0.0381	-0.1532***	0.0348	-0.3007**	0.1656	-0.5244***	0.2640	-0.5522**	0.3035	-0.9363***	0.2567
$\overline{C_I}$	0.0631***	0.0476	0.3417***	0.0889	0.4110**	0.2153	0.2951	0.4033	1.4280***	0.0875	0.8751***	0.2208
ρ_1	0.9520***	0.0709	0.8572***	0.0174	0.9254***	0.0527	0.9431***	0.0272	0.9653***	0.0144	0.4648***	0.0801
ρ_2	0.9335***	0.0609	0.8172***	0.0307	0.9707***	0.0188	0.9882***	0.0109	0.4896***	0.0262	0.4301***	0.1487
Log-L.Fn.	58.4047		70.5989		6.2416		7.2197		16.5867		38.0963	

The t test significance at the 1% (5%) significance level, is denoted by ***(**).
The variables are defined as for Equation (4.6) and Equation (4.7).

Figure 6-4 Two Country Trade Model



Source: Houck, James P.1986