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Impacts of the Chinese Fuel-Ethanol Program on the World Corn Market: An Econometric Simulation Approach

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The Chinese Government has promoted the national fuel-ethanol program since 2002 to deal with the energy security and air pollution problem. Inferior corn[1)] has been allocated as the major raw material to produce fuel-ethanol, but is inadequate for this purpose. Contrary to the national government's decision, the Chinese fuel-ethanol facilities in Heilongjiang and Jilin use normal corn, which is used for feed, food and industrial raw material. This study examines the impacts the Chinese fuel-ethanol program would have on domestic and international corn markets, by applying a newly developed Chinese corn market model. Our simulation suggests moderate impacts of the problem on the world corn market.

Key words: China, fuel-ethanol, corn, and inferior corn.

1. Introduction

In China, petroleum consumption is increasing rapidly and imports of crude oil are rising too. The increase in petroleum consumption is causing a serious air pollution problem. To deal with energy security and the air pollution problem, the Chinese Government has strongly promoted the National Fuel Ethanol[2)] Program, which is similar to the programs in Brazil and the USA, since 2002.

As a result of high economic growth, the number of cars in China has risen from 5,514 thousand in 1990 to 20,532 thousand in 2002 [5]. Chinese petroleum consumption increased from 164 million tonnes in 1990 to 346 million tonnes in 2002; and crude oil imports increased from 2,923 tonnes in 1990 to 91,126 tonnes in 2003 [7]. At present China is the second-largest petroleum consumer in the world, next to the USA [5]. In China, a shortage of energy, including petroleum, has been a serious problem since the 1990s.

The increase in petroleum consumption has caused air pollution problems. China has the second-largest CO_2 emission in the world next to the USA.[3)] The Chinese States Environmental Protection Agency estimates that 79 percent of air pollution now originates from vehicle exhausts [5]. The Chinese Government wants to improve the country's air pollution situation ahead of the 2008 Beijing Olympic Games. In China, the concept of alternative energy was expressly stated in the Five-Year Plan of 1982. In 2001, the promotion of biomass energy was expressly stated in the Five-Year Plan for the period 2001-2005.

In June 2002, the Chinese Government started to mandate the use of fuel-ethanol blend gasoline in five cities of Heilongjiang and Henan.[4)] In October 2004, the government introduced the compulsory use of a 10 percent blend of ethanol to gasoline (E10) in all areas of Heilongjiang, Jilin, Liaoning, Henan and Anhui. This means all car, truck and bus drivers in these provinces were required to use a blend of 10 percent ethanol to gasoline from October 2004. The government plans to expand the E10 program in 27 cities of Shandong, Jiangsu, Hebei, and Hubei by the end of 2005.[4)]

In the central government, the Energy Bureau of the National Development and Reform Commission leads this whole program; the Ministry of Science and Technology takes part in technical affairs; the State Grain Ad-

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ministration takes part in the supply of agricultural raw material ; and the Ministry of Agriculture takes part in the rural energy policy.

Fuel-ethanol can be produced from sugarcane, corn, wheat, rapeseed, cassava and other agricultural products and woods around the world. In China, corn and wheat comprise a major part of the raw materials for fuel-ethanol. Fuel-ethanol is produced from corn in Heilongjiang and Jilin, and from wheat in Henan and Anhui.[4] A central government subsidy is necessary to produce fuel-ethanol. The total cost of one tonne of fuel-ethanol is 4,000 yuan, a quarter of which is subsidized ; the retail price is 3,000 yuan, equivalent to the retail price of gasoline.[5] Although the government has planned to eliminate this subsidy within five to ten years, it is quite difficult to maintain fuel-ethanol production without it, a problem that exists in the US and other ethanol-producing countries, except Brazil. The central government has plenty of power to approve the operation of ethanol facilities. Although Liaoning is the main corn-producing province, the central government hasn't yet approved fuel-ethanol production from corn there. If a facility can't get approval from the central government, it cannot produce fuel-ethanol, because it can't get the raw materials or a subsidy from the central government.

The central government has limited the use of inferior agricultural products as raw materials for fuel-ethanol to mitigate the impact on the agricultural market. At present, the government prohibits the use of normal corn, traditionally used for feed, food and other industrial materials,[6] as a raw material for fuel-ethanol. However, inferior corn for fuel-ethanol can come from reserved stocks after a period of two to three years. Since 2001, the supply of this inferior corn and wheat has been decreasing, because production has decreased. In addition, the Chinese Government has promoted effective food marketing systems and tried to reduce these inferior agricultural foods since 2001. At present, there is not enough inferior corn to produce fuel-ethanol in Heilongjiang. It is estimated that production of these inferior agricultural foods will continue to decrease in the mid- to long term.

All ethanol facilities in Heilongjiang and Jilin use normal corn as a raw material for the production of fuel-ethanol, because they can't get enough inferior corn to produce it. Normal corn is used for feed, food and other industrial raw materials. Although this activity is contrary to the central government's decision, provincial governments give tacit consent for it.[7] Whether the central government will approve the use of normal corn as a raw material for fuel-ethanol production is a crucial topic for the Chinese corn market. Because the government will eliminate ending corn stocks and inferior corn, it will be very difficult to find this inferior corn in the near future. In addition, the collection costs for inferior corn will surge. To meet increasing fuel-ethanol consumption, fuel-ethanol facilities will have to improve their productivity. For the reasons mentioned above, the central government will approve the use of inferior corn as a raw material for fuel-ethanol in the near future. If the government expands the fuel-ethanol program, surging consumption of corn for fuel-ethanol will have an impact not only on the Chinese corn market but also on the world corn market.

At present, several reports and studies have noted the Chinese ethanol program. Richman [10] outlined the Chinese ethanol industry. The New Energy and Industrial Technology Development Organization in Japan (NEDO) [8] investigated the Chinese ethanol industry and facilities, and several studies have researched the implications of fuel-ethanol use on the agricultural and energy market.[8] Evans [3] focused on the links between the US ethanol market and the US corn market and analyzed the macroeconomic impacts of the ethanol market econometrically.[9] Koizumi and Yanagishima [6] examined the relationship between Brazilian sugar and the ethanol market using econometric models. However, none of these studies dealt with how the Chinese fuel-ethanol program would impact the domestic and world corn market, using an econometric model.

Our study is the first to evaluate the impact the Chinese fuel-ethanol program would have on domestic and corn markets, using a world corn model. In this study, the link between energy (ethanol) and agriculture (corn) markets is analyzed and translated into econometrically estimated structural equations based on the model. In the next section is an explanation of the Chinese corn market model we applied in evaluating it. Baseline projection figures are discussed in the third section, and the market impacts in the fourth section. The last section summarizes our conclusion.

2. The Chinese Corn Market Model

1) Overview of the Chinese corn market model

A Chinese corn market model was developed in order to analyze how the Chinese ethanol program affects not only the domestic, but also the world corn market. An econometric model has been developed as a dynamic partial equilibrium model that extends to the world corn markets. The world corn model consists of eight major corn-trading regions: China, the US, Argentina, Brazil, South Africa, Japan, the Korean Republic and the Rest of the World. These seven countries account for 92% of world corn exports, 70% of world corn production, 64% of world corn consumption, and 79% of world corn ending stocks in 2004 [4].

In the model, ethanol consumption in each country is derived exogenously. Corn markets in each country consist of production, consumption, exports, imports and ending stocks activities. The fundamental structure of our model is illustrated in the following chart (Fig. 1).

2) Model structures

Each country's corn market is described by equations for production, per capita consumption, imports, exports and ending stocks. As for the evaluation of each parameter, refer to Appendix 3. Our model is a policy simulation model, and we deem that each equation is necessary, and the magnitude of each parameter is reasonable, for building this model. Because their *t*-values and coefficients of determination are not high, we provide Appendix 3 to enable the reader to better understand the model structure. We also recognize that the number of sample data for evaluating each parameter is quite limited, because we can't get enough reliable data especially for the Chinese corn market. Although we could get a constant term in evaluating each parameter, we didn't use those constant terms for building this model. Instead of a statistically estimated constant term, we applied a calibrated constant term[10] to improve the reality for model projection activity.

Area harvested and yield equations determined corn production. The area harvested depends on the lagged domestic corn price and alternative crop prices as follows :[11]

$$\log AB_{r,t} = (1+a1)^* \log AB_{r,t-1} + a2^* \log (PC_{r,t-1} / PC_{r,t-2}) + a3^* \log (PSW_{r,t-1} / PSW_{r,t-2}) + a4^* \log (PSS_{r,t-1} / PSS_{r,t-2}) + a5^* \log (PSR_{r,t-1} / PSR_{r,t-2})$$

where AB is the area of corn harvested, a1-a5 are the parameters, PC is the domestic price of corn, PSW is the domestic producer price of wheat, PSS is the domestic producer price of soybeans, PSR is the domestic producer price of rice, r is the country and t is the time index. It is assumed that corn yield depends on the technological growth ratio as follows :

$$YH_{r,t} = YH_{r,t-1}^* (1 + a6)$$

where YH is corn yield, and a6 is the parameter. Corn production is explained as follows :

$$QP_{r,t} = AB_{r,t}^* YH_{r,t}$$

where QP is the production of corn.

Corn consumption for fuel-ethanol is determined by the exogenously provided gasoline consumption as follows.[12]

$$QE_{r,t} = (\Sigma (QG_{p,t} / (1 - BLEND))^* BLEND)^* 3.07$$

where QE is corn consumption for fuel-ethanol, QG is gasoline consumption, p is provinces, BLEND is the fuel-ethanol blend ratio relative to gasoline, and 3.07 is the average conversion rate from fuel-ethanol to corn. Corn consumption for feed depends on the domestic corn price, beef production, pork production, poultry production and dairy production.

$$\log QL_{r,t} = (1+a7)^* \log QL_{r,t-1} + a8^* \log (PC_{r,t} / PC_{r,t-1}) + a9^* \log (ALB_{r,t} / ALB_{r,t-1}) + a10^* \log (ALP_{r,t} / ALP_{r,t-1}) + a11^* \log (ALPO_{r,t} / ALPO_{r,t-1}) + a12^* \log (ALD_{r,t} / ALD_{r,t-1})$$

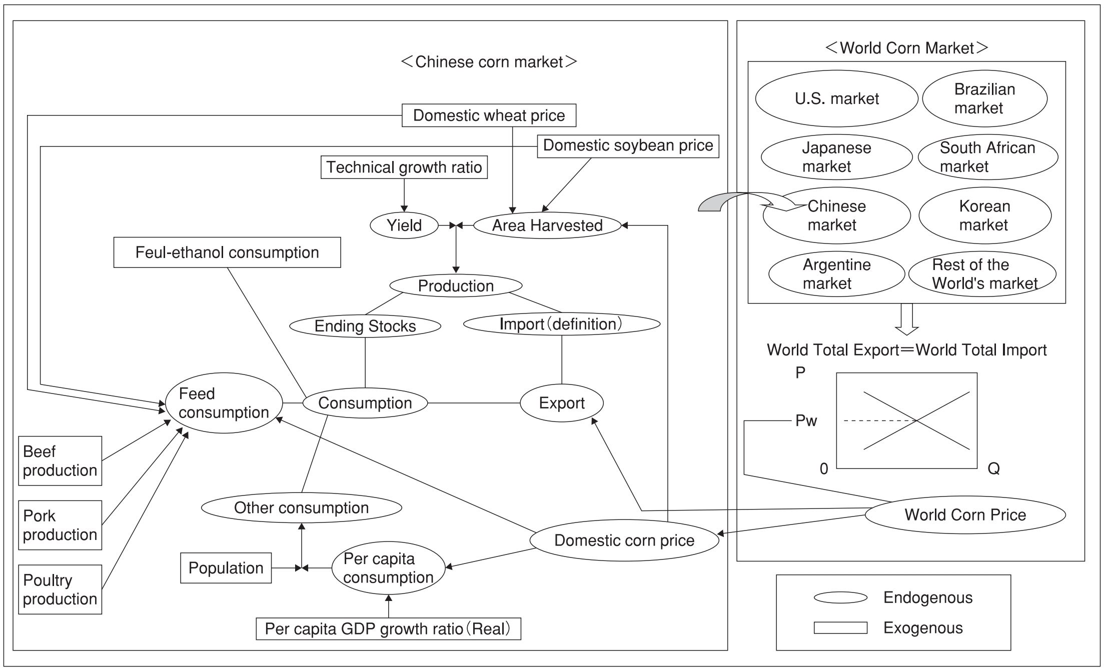

Figure 1. Chinese corn model

where QL is the feed consumption of corn, a7-a12 are the parameters, ALB is the quantity of beef production, ALP is the quantity of pork production, ALPO is the quantity of poultry production and ALD is the quantity of dairy production. Per capita corn consumption for food and other uses depends on the corn price and income.

$$\log QOP_{r,t} = (1 + a13) * \log QOP_{r,t-1} + a14* \log (PD_{r,t} / PD_{r,t-1}) + a15* \log (VV_{r,t} / VV_{r,t-1})$$

where QOP is per capita corn consumption for food and other uses, a13-a15 are the parameters and VV is the per capita income. Total corn consumption is calculated by multiplying the per capita other consumption by the country's population :

$$QO_{r,t} = QOP_{r,t} * NN_{r,t}$$

where QO is other consumption and NN is population.

Total corn consumption is the sum of fuel-ethanol consumption, feed consumption, and food and other uses.

$$QC_{r,t} = QE_{r,t} + QL_{r,t} + QO_{r,t}$$

where QC is the consumption of corn.

Chinese corn exports depend on world corn price as follows :

$$\log EX_{r,t} = (1 + a16) * \log EX_{r,t-1} + a17* \log (WP_{r,t} / WP_{r,t-1})$$

where EX is the corn export, a16-a17 are the parameters, and WP is the world corn price. For a net corn exporting country, exports are the exportable domestic market balance deficit after domestic consumption has been satisfied.

$$EX_{r,t} = IM_{r,t} + QP_{r,t} - QC_{r,t} - (ST_{r,t} - ST_{r,t-1})$$

where IM is the corn import and ST is the corn ending stocks. Corn imports in a net corn exporting country except for China depend on import prices as follows :

$$\log IM_{r,t} = (1 + a18) * \log IM_{r,t-1} + a19* \log (MP_{r,t} / MP_{r,t-1})$$

where MP is the import price of corn and a18-a19 are the parameters.

Corn imports in a net corn importing country are the exportable domestic market balance deficit remaining after domestic consumption has been satisfied.

$$IM_{r,t} = EX_{r,t} + QC_{r,t} - QP_{r,t} + ST_{r,t} - ST_{r,t-1}$$

Corn ending stocks are related to the level of production and domestic corn prices in a net corn exporting country as follows :

$$\log ST_{r,t} = (1 + a20) * \log ST_{r,t-1} + a21* \log (QP_{r,t} / QP_{r,t-1}) + a22* \log (PC_{r,t} / PC_{r,t-1})$$

where a20-a22 are parameters. For a net corn importing country, ending stocks are related to the level of consumption and domestic corn prices as follows :

$$\log ST_{r,t} = (1 + a23) * \log ST_{r,t-1} + a24* \log (QC_{r,t} / QC_{r,t-1}) + a25* \log (PC_{r,t} / PC_{r,t-1})$$

where a23-a25 are the parameters.

3) World market equilibrium and price linkage

For each simulation year, the model determines gross exports and imports for each country. A world corn market equilibrium price is then obtained from the following equilibrium conditions through the use of the Gauss-Seidel algorithm. World corn price refers to the world corn market clearing price.

$$\sum EX_{r,t} = \sum IM_{r,t}$$

where r is each country and t is the time index.

The domestic corn producer price and import price are linked to the world corn price through constant price transmission elasticity as follows.

$$\log PC_{r,t} = a26* \log (WP_{r,t} / WP_{r,t-1})$$

$$MP_{r,t} = (WP_t) * (1 + TS_{r,t})$$

where a26 is the parameter, and where TS is the *ad valorem tariff* ratio for corn.

Data for the corn market[13] are taken from the USDA's PS & D [4]. Chinese gasoline consumption has been collected from publications issued by the Chinese National Bureau of Statistics [7].

3. Projections

1) Assumptions

Our baseline projection is based on a series of assumptions about the general economy, agricultural policies, and technological changes in the exporting and importing countries during the projection period. The exogenous assumption regarding projected consumption for gasoline in China was taken from International Energy Outlook 2002 [2].

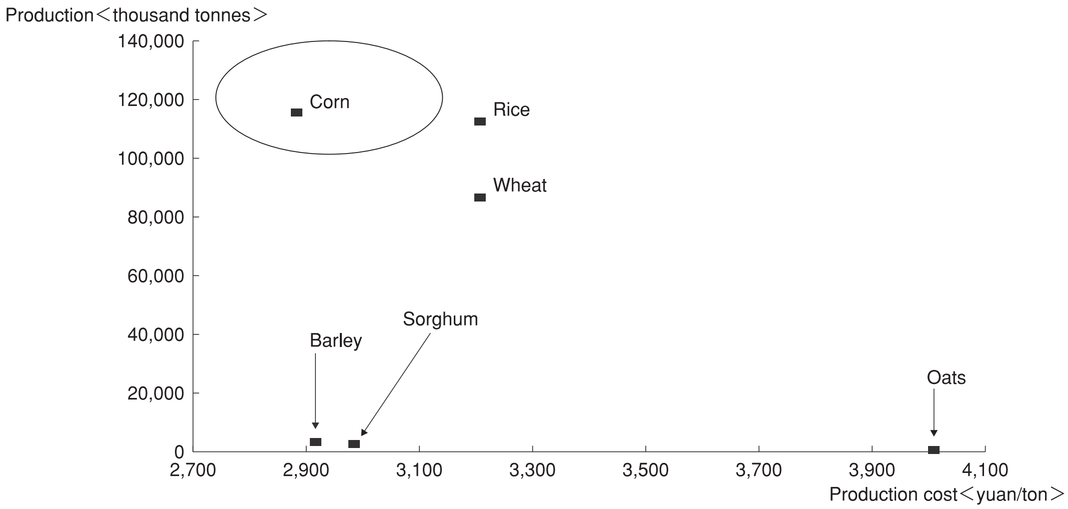

Figure 2. Chinese cereal production and production cost (2003)

Note : Production data were derived from FAS, USDA, "PS&D." Production cost was estimated by data from the Chinese National Development and Reform Commission, and production yield data from ERS, USDA "The Energy Balance of Corn Ethanol : An Update" (2002).

Table 1. Corn consumption for fuel ethanol (baseline projection) (thousands tonnes)

	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Fuel-ethanol consumption, corn equivalent : (1) *3.07	2,363.3	2,535.8	2,708.3	2,880.9	3,053.4	3,225.9	3,398.5	3,628.0	3,857.5	4,087.0	4,316.5
Fuel-ethanol consumption : (1)=(2)+(3)+(4)	769.8	826.0	882.2	938.4	994.6	1,050.8	1,107.0	1,181.8	1,256.5	1,331.3	1,406.0
Fuel-ethanol consumption in Jilin (2)	126.2	135.4	144.6	153.8	163.0	172.3	181.5	193.7	206.0	218.2	230.5
Fuel-ethanol consumption in Heilongjiang (3)	336.4	361.0	385.5	410.1	434.7	459.2	483.8	516.5	549.1	581.8	614.5
Fuel-ethanol consumption in Liaoning (4)	307.2	329.6	352.0	374.5	396.9	419.3	441.7	471.6	501.4	531.2	561.1

Another exogenous assumption, the projected world crude oil price, was derived from the US Department of Energy's Annual Energy Outlook 2005 [11]. In this USDE high B world oil price case scenario, the world crude oil price is expected to increase at a rate of 1.2 % per year from 2004 to 2014. The exogenous wheat price, soybean price and rice price, beef production, pork production, poultry production and dairy production were taken from OECD [9] and ERS, USDA [1]. Population data for all countries were taken from official United Nations population estimates (medium variant). GDPs were also treated as exogenous variables and their growth rate assumptions were based on World Bank economic forecasts.

We also assumed that current agricultural polices will continue in all countries throughout the projection period. Following the general adopted procedures, we assumed normal weather and historical rates of technological innovation. New WTO agricultural agreements were not taken into account in the model. Market access was frozen at levels prevailing in the year 2000. Regional free trade areas were assumed not to expand.

It is assumed the Chinese Government will promote the E10 program in the future, because the energy security problem and the air pollution problem are expected to be serious in the future. In all alternative fuel vehicles contributing a lower emission of CO_2, bio-ethanol is superior to other vehicle-powering fuels, such as bio-diesel, and methanol, and fuel-cell and electrically-powered vehicles, with regard to the transfer costs from the current vehicle to an alternative fuel-powered vehicle. Fuel-ethanol made from corn has the highest production yield among all agricultural products at present.[14] It is possible to get a technical transfer from the USA at a lower price. In China, corn production is larger than for any other product and the production cost is lower than for any other product, including wheat and rice. It means the Chinese ethanol production from corn has the advantage, compared with other crops (Fig. 2).

In China, corn used to be a staple food ; but today it is not a staple food, such as wheat and rice, because Chinese eating habits have changed recently, becoming more modernized and westernized. As a result of this, the government is assumed to be promoting the fuel-ethanol program based on corn. It is assumed that the government will approve of normal corn as a raw material for fuel-ethanol in the near future.

We assumed that the Chinese Government will maintain and promote the fuel-ethanol program, based on the pilot plan to use fuel-ethanol for automobiles, decided by the Chinese Government in 2002. In the US, the use of MTBE (Methyl Tertiary Butyl Ether) is expected to be in force in 17 states that have passed the relevant legislation.[15] A federal ban on MTBE is not expected during the projection period. We assumed that Brazil and India will maintain their fuel-ethanol programs based on sugarcane.

2) Projected world and Chinese corn market to the year 2014/2015

Based on the central government's 2002 pilot plan for using fuel-ethanol in automobiles, we have assumed the government will maintain and proceed with the E10 program in Heilongjiang, Jilin, Liaoning, Henan and Anhui. Shandong, Jiangsu, Hebei and Hubei are assumed to start the E10 program from 2006 in 27 cities. Jilin is assumed to meet

Table 2. Corn consumption for fuel ethanol (scenario projection) (thousands tonnes)

	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15
Fuel-ethanol consumption, corn equivalent : (1) * 3.07	6,240.0	6,685.4	7,130.8	7,576.3	8,168.8	8,761.3	9,353.8	9,946.3
Fuel-ethanol consumption : (1) = (2) + (3)	2,032.6	2,177.7	2,322.7	2,467.8	2,660.8	2,853.8	3,046.8	3,239.8
Fuel-ethanol consumption (baseline) (2)	938.4	994.6	1,050.8	1,107.0	1,181.8	1,256.5	1,331.3	1,406.0
Additional fuel-ethanol consumption (from maize) : (3) = (5) − (4)	1,094.2	1,183.1	1,272.0	1,360.8	1,479.1	1,597.3	1,715.6	1,833.8
Fuel-ethanol consumption (from wheat) (4)	390.0	390.0	390.0	390.0	390.0	390.0	390.0	390.0
4 Province total : (5) = (6) + (7) + (8) + (9)	1,484.2	1,573.1	1,662.0	1,750.8	1,869.1	1,987.3	2,105.6	2,223.8
Fuel-ethanol consumption in Hebei (6)	369.2	391.3	413.4	435.5	464.9	494.4	523.8	553.2
Fuel-ethanol consumption in Shandong (7)	280.5	297.3	314.1	330.8	353.2	375.5	397.9	420.2
Fuel-ethanol consumption in Hubei (8)	369.2	391.3	413.4	435.5	464.9	494.4	523.8	553.2
Fuel-ethanol consumption in Jiangsu (9)	465.3	493.2	521.1	548.9	586.0	623.1	660.1	697.2

ethanol consumption in Liaoning. Henan and Anhui are assumed to meet ethanol consumption in Shandong, Jiangsu, Hebei and Hubei. In this baseline scenario, each province's gasoline consumption data in 2002 was derived from the Chinese Energy Statistical Report [7]. Projected gasoline consumption in China was taken from International Energy Outlook 2004 [2]. Based on these data, we projected the gasoline consumption in Heilongjiang, Jilin and Liaoning (Table 1), and we estimated fuel-ethanol consumption in each province from these projections.[16] Corn consumption for fuel-ethanol is projected to increase from 2,363 metric tonnes in 2004/05[17] to 4,316 metric tonnes in 2014/15.

World corn consumption and production were projected to increase by 2.0% per annum from 2004/2005 to 2014/2015. The country that contributes most to this increase in world corn consumption is China. World corn exports and imports are projected to increase by 2.7% per annum during this period. The world corn price is projected to increase steadily from 2.3 in 2004/15 to 3.0 dollars/bushel in 2014/15.

As a result of the Chinese fuel-ethanol program, corn consumption for fuel-ethanol is projected to increase by 7.1% per annum from 2004/05 to 2014/15. Total Chinese corn consumption is projected to increase by 2.0% per annum during this period. As a result of the rapid growth of corn consumption, Chinese corn imports are projected to increase by 45.2% per annum during this period. China is expected to change from a net corn exporter to a net corn importer during this period. It is also projected to change to a net-import country from 2007/08 and its imports are projected to increase to 6,094 thousand metric tonnes in 2014/15. This volume is below the Chinese current TRQ level (7,200 thousand metric tones). China is expected to become one of the major corn importers in the world, next to Japan and the Korean Republic.

US corn production is projected to increase by 1.5% per annum from 2004/05 to 2014/15, while US corn exports are projected to increase by 3.4% per annum, occupying a dominant share (68.0%) of world corn exports in 2014/15. The USA is expected to be the biggest corn producer and exporter during this period. Argentine corn production is projected to increase by 2.8% per annum from 2004/05 to 2014/15. Its exports are projected to increase by 2.3% per annum, occupying a dominant share (16.2%) of world corn exports in 2014/15. Brazil's corn production is projected to increase by 2.8% per annum from 2004/05 to 2014/15. Its exports are projected to increase by 9.7% per annum during this period. Japanese corn consumption and imports are projected to increase by 0.2% per annum from 2004/05 to 2014/15. Korea's corn consumption and imports are predicted to increase by 1.6% and 1.8% during this period.

4. Impact of the Chinese Ethanol Program on Global and Chinese Corn Markets

1) Alternative scenario

The government has started to expand the fuel-ethanol program, and from 2006 will extend the E10 program in the 27 cities of Shandong, Jiangsu, Hebei, and Hubei. The government is expected to expand this program for the four provinces after the testing stage.

However, a crucial issue in this case is whether Chinese fuel resources can meet the increasing consumption of fuel-ethanol.

It is very difficult to combine the chemical characteristics of ethanol and gasoline with each other. At present, gasoline blended with ethanol can't be transferred by pipeline all over the world. Even in the US, blended gasoline is transferred mainly by tank truck, not pipeline. The Chinese transportation system and infrastructure are in a developmental stage, and the fuel-ethanol transfer from north to south is expected to be very difficult and unrealistic during this projection period. To increase fuel-ethanol production, it would be realistic to assume that the Chinese Government will approve the production of fuel-ethanol from corn in Liaoning and Shandong, which are major corn-producing provinces. They can provide not only for the needs of their own fuel-ethanol consumption but also for the consumption needs of neighboring provinces, such as Jiangsu and Hebei.

Fuel-ethanol production from wheat is inferior to that from corn from the point of view of cost, production and the fact that it is a staple food. At present, fuel-ethanol production from other agricultural products and wood is in an experimental stage. It is assumed Henan and Anhui can produce fuel-ethanol to meet their provincial consumption needs. Although they can produce less than 390,000 tonnes to meet the consumption of the neighboring provinces decided by the national government, their facilities can't produce more than 390,000 tonnes of fuel-ethanol.[4)]

As an alternative scenario to this study, we assumed that the Chinese Government will start the E10 program in four provinces: Shandong, Jiangsu, Hebei and Hubei. As a result of this new program, nine provinces are assumed to promote the fuel-ethanol program on a provincial level from 2007/08. This means that all gasoline which is sold in the nine provinces has to be blended with 10% of fuel-ethanol.

As a result of the expanded program, corn consumption for fuel-ethanol is predicted to increase from 6,240 thousand metric tonnes in 2007/08 to 9,946 thousand metric tonnes in 2014/15 (Table 2).[16)] In 2014/15, corn consumption for fuel-ethanol is assumed to be 2.3 times that of the baseline projection.

2) Impact on world corn markets

As a result of the E10 program in nine provinces from 2007/08, Chinese corn con-

Table 3. Impact on world corn consumption (2014/15)

	Scenario/Baseline
World total	0.4%
China	3.4%
USA	−0.3%

Table 4. Impact on world corn import (2014/15)

	Scenario/Baseline
World total	3.4%
China	89.1%
USA	0.0%
Japan	−0.1%
Korean Republic	−0.3%

Table 5. Impact on world corn production (2014/15)

	Scenario/Baseline
World total	0.4%
China	0.1%
USA	0.7%
Argentina	0.7%
Brazil	0.3%
South Africa	0.0%

Table 6. Impact on world corn export (2014/15)

	Scenario/Baseline
World total	3.4%
China	0.3%
USA	4.1%
Argentina	1.2%
Brazil	4.4%
South Africa	1.0%

Table 7. Impact on corn prices (2014/15)

	Scenario/Baseline
World (Chicago No. 2 yellow)	1.5%
China	0.4%
USA	1.4%

Note: Each percentage means (Scenario (2014/15)/Baseline (2014/15) − 1) *100.

sumption is predicted to increase by 3.4% in 2014/15 (Table 3). Chinese corn imports are predicted to increase by 89.1% in 2014/15 (Table 4).

World corn exports are predicted to increase by 3.4%, because the higher world corn price will stimulate major corn-exporting countries to increase their exports from 2007 with a one-year lag (Table 6). A higher world corn price will benefit corn-exporting countries. The country that contributes most to this increase is the United States. Exports from the US are predicted to increase by 4.1 %. The US is assumed to remain the world's biggest corn-producing and exporting country. As a result of higher corn prices, US farmers, especially in the Corn Belt region, are projected to shift from soybeans to corn production with a one-year lag. The export crop is predicted to increase by 2,841 thousand metric tonnes in 2014/15. Exports from Argentina and Brazil are predicted to increase by 1.2% and 4.4%, respectively. The potential for these countries to increase corn production is assumed to be large. In Brazil, particularly, there are plenty of arable lands in the northern and central areas. Trade partnerships between China and Brazil have been tightened nowadays. The Chinese Government has offered to provide financial investment for export facilities, such as harbor facilities and a transportation system between the farm gate and the harbor. It is assumed that the Chinese Government will promote this economic relationship, because it is very interested in Brazilian natural resources, such as corn, soybeans, sugar, iron ore and other commodities.

Although Chinese corn imports are predicted to surge, for net importing countries, such as Japan and the Korean Republic, imports from Japan and the Korean Republic are predicted to decrease by 0.1% and 0.3%. The imports from the Japan and the Korean Republic are predicted to decrease by 18 thousand metric tonnes and 35 thousand metric tonnes in 2014/15. The impact for the Japanese and Korean corn market is predicted to be quite small, compared with other markets, such as the Chinese market.[18] In Japan, feed consumption depends on the domestic mixed feed price, beef production, pork production, and poultry production. The mixed feed price is a crucial factor impacting feed consumption in Japan. The price is set by private feed companies, which decide the price by taking into account the world corn price, the prices of other feed grains, freight and exchange rates. The world corn price is not a single price determinant of the mixed feed grain price. Higher world corn prices haven't affected the consumption of Japanese domestic feed corn elastically. World corn imports are predicted to increase by 3.4%.

As a result, world corn prices are predicted to increase by 1.5% in 2014/15 (Table 7).

5. Conclusion

With Chinese oil imports rising rapidly as a result of motorization, it is expected that the Chinese Government will expand the fuel-ethanol program in the future. The expansion of the program is expected to mitigate the dependence on oil imports, mitigate the energy security problem and reduce air-pollution problems. As a result of the insufficiency of inferior corn, Chinese fuel-ethanol is made mainly from normal corn in most facilities, contrary to the national government's decision. In this study, we hypothesized that the expansion of the Chinese fuel-ethanol program would impact not only the domestic corn market but also world corn markets. As a result of the expanded Chinese fuel-ethanol program from 2007, world corn trade and prices are predicted to increase. Our estimate shows that the magnitude of the world corn price hikes will persist for years. Although Chinese corn imports are expected to surge, for net importing countries, such as Japan and the Korean Republic, the impact is predicted to be quite small. A higher corn price will benefit corn- exporting countries. The country that contributes most to this increase is the United States. Exports from the US are predicted to increase by 3.7%. Corn exporters are expected to receive material benefits with a one-year time lag. As a result, the world corn price is predicted to increase by 1.6% in 2014/15.

As a result of our analysis using the econometric model, we concluded that the program is predicted to impact not only the domestic corn market but also world corn markets. Our simulation result suggests moderate impacts of the Chinese ethanol problem on the world corn market. At present, the government has not shown a political intention to control corn markets. This program has created new corn consumption for the Chinese corn market. As a result of the increase of fuel-ethanol, corn consumption is projected to increase rapidly. This means that corn consumption for fuel-ethanol is competing with corn consumption for feed, food and other industries.

Although the Chinese Government has stressed that this program is an effective policy tool to mitigate domestic energy security problems, it can raise the new argument that energy security will conflict with food security, competing to use the same natural resource (corn). This argument has already arisen in Brazil and the US between agricultural products (sugarcane and corn) and energy (fuel-ethanol). The world's largest corn producer and exporter (US) and the second-largest producer (China) operate the same fuel-ethanol program at the same time. We deem that these concurrent programs can have more impact on world corn and corn-importing countries' food security situation than a single program. We deem that the future fuel-ethanol program of both countries will be worthy of notice for the agricultural market. Future directions for this study are to combine the analysis of the impact of the US and Brazilian fuel-ethanol programs, the world's largest corn-based fuel-ethanol producers, with world crude oil price changes and changes in the State's ethanol program.

1) Inferior corn is unsuitable for food use and is delivered from reserved stock to the market after a 2-3 year reserved period.
2) In this study, ethanol means biomass ethanol. It doesn't include synthetic ethanol made from fossil fuels.
3) Data were derived from Oak Ridge National Laboratory (2000).
4) National Development and Reform Commission's "Pilot plan of fuel-ethanol for automobile use" March, 2002.
5) Interview with the National Development and Reform Commission in January 2005.
6) Other industrial raw materials are used for adhesives, gummed tape, polished goods and other products.
7) Interview with Heilongjiang Academy of Agricultural Science in January 2005.
8) This study isn't directly related to the report from NEDO[8]. We used the report to review the Chinese ethanol program.
9) Evans [3] covered the US corn and ethanol market. He didn't cover the international corn and ethanol market.
10) The coefficient of calibration obtained to correct each market activity for the first projection year (2005/06) is equivalent to updated estimated data (2005/06), published by FAS, USDA[4].
11) This model is a policy simulation model, reflecting time-series price changes. We applied lagged variables for building this model. The main advantage to applying them is preventing spurious regression and eliminating trends.
12) Corn consumption for fuel-ethanol in the US is derived endogenously. It depends on the domestic gasoline price, which is determined by the exogenously provided crude oil price.
13) The Chinese Government hasn't published corn ending stocks data. For evaluation of the parameter for Chinese ending stocks, we use estimated data from USDA's PS & D [4].
14) According to the USDA, 340 liters of ethanol is produced from one tonne of corn ; 300 liters of ethanol is produced from one tonne of wheat and rice, 80 liters of ethanol is produced from one tonne of potatoes.
15) California, Colorado, Connecticut, Indiana, Iowa, Illinois, Kansas, Kentucky, Maine, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio, South Dakota, and Washington.
16) We estimated gasoline consumption in each province from the national growth ratio derived from gasoline projection data [2]. We applied the national growth ratio to each province, because we can't get the growth ratio for each province. The growth ratio for one provinces' fuel-ethanol consumption, derived constant fuel-ethanol blend ratio to gasoline, is the same ratio as other provinces.' As for estimation from gasoline consumption to corn consumption for fuel-ethanol, please refer to lines 31 to 41 on Page 28 (right side).
17) Crop year 2004/05 means the period from September 2004 to August 2005.
18) Chinese corn imports on predicted to increase by 5, 430 thousand metric tonnes in 2014/15.

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Appendix 1 : Estimated parameters

Table A1.

Coefficient	Dependent variables	Explanatory variables	China	USA	Argentina	Japan	Brazil	Korean Republic	South Africa	Rest of the world
a1	Area harvested	Coefficient of calibration	0.0110	0.0142	0.0010	—	0.0200	—	0.0080	0.0131
a2		Domestic price of corn	0.1710	0.4800	0.6273	—	0.4009	—	0.0350	0.2300
a3		Domestic producer price of wheat	−0.0914	−0.0700	−0.4435	—	−0.1019	—	−0.0900	—
a4		Domestic producer price of soybeans	—	−0.0418	−0.1620	—	−0.1313	—	—	—
a5		Domestic producer price of rice	—	—	—	—	−0.1525	—	—	—
a6	Yield	Growth ratio	0.0350	0.0100	0.0020	—	0.0250	—	0.0270	0.0270
a7	Feed consumption	Coefficient of calibration	0.0012	0.0100	0.0500	0.0150	0.0100	0.0170	0.0100	0.0380
a8		Domestic price of corn	−0.1520	−0.2607	−0.3655	−0.3080	−0.3000	−0.3426	−0.3000	−0.4000
a9		Beef production	0.2997	0.4478	0.2250	0.1300	0.2900	—	—	0.1110
a10		Pork production	0.3004	0.1080	—	0.2860	—	0.3373	—	0.3190
a11		Poultry production	—	—	—	0.2010	0.1970	0.4982	—	—
a12		Dairy production	—	—	0.3679	—	0.2760	—	—	0.2360
a13	Per capita other corn consumption	Coefficient of calibration	0.0420	0.0020	0.0100	0.0450	0.0100	0.0100	0.0100	0.0400
a14		Domestic price of corn	−0.0730	−0.0442	−0.0864	−0.1043	−0.2712	−0.1551	−0.1859	−0.2780
a15		Per capita income	0.0588	0.0079	0.0202	0.1952	0.0165	0.2122	0.0611	0.1424
a16	Export	Coefficient of calibration	−0.1000	—	—	—	—	—	—	—
a17		World corn price	0.2041	—	—	—	—	—	—	0.2771
a18	Import	Coefficient of calibration	—	−0.0200	−0.0100	—	−0.0400	—	0.0100	—
a19		Import corn price	—	−0.0231	−0.7194	—	−0.2286	—	−0.3980	—
a20	Ending stocks	Coefficient of calibration	−0.1600	0.0100	0.0200	—	−0.0100	—	0.0100	—
a21		Domestic corn production	0.1904	0.1424	0.7302	—	—	—	0.3144	—
a22		Domestic price of corn	—	−0.2780	−0.4834	—	−0.1478	—	−0.0965	—
a23		Growth ratio	—	—	—	0.0100	—	0.0100	—	0.0100
a24		Domestic corn consumption	—	—	—	0.8759	—	0.6300	—	0.1424
a25		Domestic price of corn	—	—	—	−0.3685	—	−0.0956	—	−0.2780
a26	Domestic price transmission elasticity	World corn price	0.3015	0.5249	0.8262	0.2050	0.6003	0.7377	0.4251	—
TS	Import price	Ad valorem tariff ratio	0.0100	0.0000	0.0800	0.0000	0.0800	3.2300	0.0217	—

Note : "—" means doesn't apply to the country or region.

Appendix 2 : Baseline projection

Table A 2-1. Exogenous variables

	Unit	Source	2004/05	2014/15 (Projection)
World crude oil price	Dollar/barrel	High B world oil price, U. S. Department of Energy, Annual Energy Outlook 2005, (2005)	35. 0	39. 9
Gasoline consumption, China	MT	International Energy Outlook 2004 (2005)	49. 6	97. 8
Wheat domestic price, China	CNY/t	Free market price, OECD (2005)	854. 0	866. 0
Pork production, China	kt cwe	OECD (2005)	832. 0	1, 018. 0
Beef production, China	kt cwe	OECD (2005)	6, 691. 0	9, 867. 0
Domestic soybeans price, USA	Dollar/t	Soybean meal price, ERS, USDA (2005)	160. 0	176. 0
Domestic wheat price, USA	Dollar/bushel	Farm price, ERS, USDA (2005)	3. 4	3. 6
Beef production, USA	Mil. ibs	ERS, USDA (2005)	24, 599. 0	28, 042. 0
Pork production, USA	Mil. ibs	ERS, USDA (2005)	20, 595. 0	23, 172. 0
Dairy production, USA	Mil. ibs	ERS, USDA (2005)	173. 7	195. 2
Domestic soybeans price, Argentina	2004/05=1	Export price, f. o. b. Argentine ports, OECD (2004)	1. 0	1. 1
Domestic wheat price, Argentina	ARS/t	Export price, f. o. b. Argentine ports, OECD (2005)	405. 0	465. 0
Beef production, Argentina	kt cwe	OECD (2005)	2, 693. 0	3, 195. 0
Dairy production, Argentina	mt pw	OECD (2005)	9. 3	13. 9
Beef production, Japan	kt cwe	OECD (2005)	514. 0	515. 0
Pork production, Japan	kt cwe	OECD (2005)	1, 276. 0	1, 042. 0
Poultry production, Japan	kt rtc	OECD (2005)	1, 248. 0	1, 056. 0
Domestic soybeans price, Brazil	2004/05=1	Producer price, OECD (2004)	1. 0	1. 2
Domestic wheat price, Brazil	BRL/t	Producer price, OECD (2005)	429. 0	630. 0
Domestic rice price, Brazil	2004/05=1	Producer price, OECD (2004)	1. 0	2. 0
Beef production, Brazil	kt cwe	OECD (2005)	7, 485. 0	9, 729. 0
Poultry production, Brazil	kt rtc	OECD (2005)	8, 274. 0	11, 185. 0
Dairy production, Brazil	mt pw	OECD (2005)	23. 8	29. 7
Pork production, Korean Republic	kt cwe	OECD (2005)	1, 011. 0	1, 359. 0
Poultry production, Korean Republic	kt rtc	OECD (2005)	590. 0	674. 0
Domestic wheat price, South Africa	2004/05=1	Producer price, OECD (2004)	1. 0	1. 1

Table A 2-2. Projected corn prices

	Unit	Source	2004/05	2014/15 (Projection)
World corn price	Dollars/bushel	Corn No. 2 yellow, Chicago, ERS, USDA (2005)	2.2	3.0
Domestic corn price, USA	Dollars/bushel	Corn farm price, ERS, USDA (2005)	2.1	2.8
Domestic corn price, China	CNY/t	Maize free market price, OECD (2005)	1,215.0	1,461.5
Domestic corn price, Argentina	ARS/t	Corn export price, f.o.b., Argentinean ports	307.0	473.2
Domestic corn price, Brazil	1995=1	Corn producer price, OECD (2004)	2.6	3.4
Domestic mixed feed price, Japan	Japanese yen/t	Mixed feed price, all livestocks weighted average, MAFF, Japan (2005)	39,013.0	41,770.0
Domestic corn price, Korean Republic	1995=1	Corn Import price, OECD (2004)	1.2	1.6
Domestic corn price, South Africa	Dollars/t	White corn price, ERS, USDA (2005)	131.5	163.8

Table A 2-3. Corn production (thousand metric tonnes)

	1994/95	2004/05	2009/10 (projection)	2014/15 (projection)	Growth rate 94/95-2004/05	Growth rate 2004/05-2014/15
World	558, 985	668, 768	732, 035	831, 598	1. 6%	2. 0%
China	99, 280	123, 610	138, 777	157, 794	2. 0%	2. 2%
USA	255, 295	278, 409	293, 310	328, 231	0. 8%	1. 5%
Argentina	11, 360	17, 833	19, 882	24, 088	4. 2%	2. 8%
Japan	2	1	1	1	−6. 1%	0. 0%
Brazil	37, 440	41, 167	46, 341	56, 061	0. 9%	2. 8%

Source : FAS, USDA, PS &D (1994/95, 2004/05), Authors' projections (2009/10, 2014/15).
Note : 1) Thouth we made annual projections from 2005/06-2014/15, we show mid-term and final terms' projections briefly in this study.
2) Thouth we projected 8 countries' markets, we show the main countries briefly in this study.
3) As for Table A 2-4, 2-5 and 2-6, sources and notes are the same as in this table.

Table A 2-4. Corn consumption (thousand metric tonnes)

	1994/95	2004/05	2009/10 (projection)	2014/15 (projection)	Growth rate 94/95-2004/05	Growth rate 2004/05-2014/15
World	538, 166	668, 743	733, 276	832, 144	2. 0%	2. 0%
China	97, 000	131, 300	144, 139	162, 971	2. 8%	2. 0%
USA	182, 251	218, 579	239, 910	259, 402	1. 7%	1. 6%
Argentina	5, 479	5, 100	6, 355	7, 682	−0. 6%	3. 8%
Japan	16, 450	16, 817	16, 051	17, 105	0. 2%	0. 2%
Brazil	36, 000	40, 367	44, 780	49, 523	1. 0%	1. 9%

Table A 2-5. Corn export (thousand metric tonnes)

	1994/95	2004/05	2009/10 (projection)	2014/15 (projection)	Growth rate 94/95-2004/05	Growth rate 2004/05-2014/15
World	66, 058	75, 459	79, 418	101, 096	1. 2%	2. 7%
China	1, 333	5, 518	3, 298	1, 980	13. 8%	−8. 9%
USA	55, 311	47, 811	53, 344	68, 768	−1. 3%	3. 4%
Argentina	5, 782	12, 750	13, 524	16, 401	7. 5%	2. 3%
Japan	0	0	0	0	—	—
Brazil	56	2, 580	2, 321	7, 142	41. 7%	9. 7%

Table A 2-6. Corn import (thousand metric tonnes)

	1994/95	2004/05	2009/10 (projection)	2014/15 (projection)	Growth rate 94/95-2004/05	Growth rate 2004/05-2014/15
World	68, 911	74, 934	79, 419	101, 096	0. 8%	2. 7%
China	4, 287	101	6, 903	6, 094	−28. 9%	45. 2%
USA	243	289	260	234	1. 6%	−1. 9%
Argentina	1	15	13	11	27. 9%	−2. 7%
Japan	16, 481	16, 760	16, 045	17, 105	0. 2%	0. 2%
Brazil	1, 407	917	726	571	−3. 8%	−4. 2%

Appendix 3 : Major estimated equations

Area of corn harvested in China

$$\log AB_{r,t} = \underset{(46.8096)}{10.1229} + (1 + 0.0100) * \log AB_{r,t-1} + \underset{(1.1278)}{0.1710} * \log(PC_{r,t-1}/PC_{r,t-2}) + \underset{(-0.6637)}{(-0.0914)} * \log(PSW_{r,t-1}/PSW_{r,t-2})$$

$R^2 = 0.6196$, $\bar{R}^2 = 0.5342$, n = 10 (from 1994 to 2003), DW = 1.95

Area of corn harvested in Brazil

$$\log AB_{r,t} = \underset{(32.8054)}{9.5696} + (1 + 0.020) * \log AB_{r,t-1} + \underset{(4.02266)}{0.4009} * \log(PC_{r,t-1}/PC_{r,t-2}) + \underset{(-2.4206)}{(-0.1019)} * \log(PSW_{r,t-1}/PSW_{r,t-2}) + \underset{(-1.4145)}{(-0.1313)} * \log(PSS_{r,t-1}/PSS_{r,t-2}) + \underset{(-1.2828)}{(-0.1525)} * \log(PSR_{r,t-1}/PSR_{r,t-2})$$

$R^2 = 0.8517$, $\bar{R}^2 = 0.7529$, n = 11 (from 1994 to 2004), DW = 2.159

Feed consumption of corn in China

$$\log QL_{r,t} = \underset{(40.4888)}{11.1859} + (1 + 0.0012) * \log QL_{r,t-1} + \underset{(-2.1403)}{(-0.151967)} * \log(PC_{r,t}/PC_{r,t-1}) + \underset{(0.9659)}{0.2997} * \log(ALB_{r,t}/ALB_{r,t-1}) + \underset{(0.5309)}{0.3004} * \log(ALP_{r,t}/ALP_{r,t-1})$$

$R^2 = 0.9812$, $\bar{R}^2 = 0.9531$, n = 11 (from 1993 to 2003), DW = 2.2652

Feed consumption of corn in the Korean Republic

$$\log QL_{r,t} = \underset{(29.5109)}{7.6889} + (1 + 0.017) * \log QL_{r,t-1} + \underset{(-1.7869)}{(-0.3426)} * \log(PC_{r,t}/PC_{r,t-1}) + \underset{(1.5746)}{0.3373} * \log(ALP_{r,t}/ALP_{r,t-1}) + \underset{(2.0594)}{0.498159} * \log(ALPO_{r,t}/ALPO_{r,t-1})$$

$R^2 = 0.9519$, $\bar{R}^2 = 0.9279$, n = 16 (from 1978 to 2001), DW = 1.9365

Per capita other corn consumption in Japan

$$\log PQO_{r,t} = \underset{(-34.2880)}{-3.9983} + (1 + 0.045) * \log PQO_{r,t-1} + \underset{(-1.7132)}{(-0.1043)} * \log(PD_{r,t}/PD_{r,t-1}) + \underset{(4.7361)}{(0.1952)} * \log(VV_{r,t}/VV_{r,t-1})$$

$R^2 = 0.74674$, $\bar{R}^2 = 0.6777$, n = 15 (from 1988 to 2003), DW = 2.006

Corn exports in China

$$\log EX_{r,t} = \underset{(1.1752)}{3.0369} + (1 - 0.100) * \log EX_{r,t-1} + \underset{(1.8918)}{0.2041} * \log(WP_{r,t}/WP_{r,t-1})$$

$R^2 = 0.7056$, $\bar{R}^2 = 0.6215$, n = 10 (from 1994 to 2003), DW = 1.9697

Corn imports in Argentina

$$\log IM_{r,t} = \underset{(-1.0935)}{-0.9469} + (1 - 0.0100) * \log IM_{r,t-1} + \underset{(-0.4456)}{(-0.7194)} * \log(MP_{r,t}/MP_{r,t-1})$$

$R^2 = 0.5137$, $\bar{R}^2 = 0.4056$, n = 12 (from 1992 to 2003), DW = 1.9999

Note : The figures under each elasticity are *t*-values, except for coefficient of calibration.