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# Policy Options for China's Bio-ethanol Development and the Implications for Its Agricultural Economy

*Huanguang Qiu, Jikun Huang, Michiel Keyzer, Wim van Veen**

Abstract

*The present paper analyzes the potential impacts of bio-ethanol expansion on agricultural production, food prices and farmers' incomes in different regions of China. The results show that increase in demand for feedstock to produce bio-ethanol will lead to large increase in the prices of agricultural products. The increase in prices will trigger a significant rise in the production of feedstock at the cost of lower rice and wheat production. The study also reveals that the impacts of bio-ethanol on farmers' incomes vary largely among regions and farmer groups. Given the expected expansion of bio-ethanol production in the future, and the limited land resources for feedstock production in China, the viability of different crops as feedstock for bio-ethanol requires careful analysis before a large-scale expansion of China's bio-ethanol program. Bio-ethanol production in China should be relying more on the second generation of bio-ethanol technologies (i.e. using celluloses to produce bio-ethanol), and China's government should increase research investment in this field.*

Key words: agricultural development, bio-ethanol, policy options

JEL codes: Q16, Q18, O13

* Huanguang Qiu, Research Fellow, Center for Chinese Agricultural Policy, Institute of Geographic Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China. Email: hgqiu.ccap@igsnrr.ac.cn; Jikun Huang, Professor and Director, Center for Chinese Agricultural Policy, Institute of Geographic Sciences and Natural Resource Research, Chinese Academy of Sciences, Beijing, China. Email: jkhuang.ccap@igsnrr.ac.cn; Michiel Keyzer, Professor and Director, Center for World Food Study, Free University, the Netherlands. Email: m.a.keyzer@sow.vu.nl; Wim van Veen, Research Fellow, Center for World Food Study, Free University, the Netherlands. Email: w.c.m.vanveen@sow.vu.nl.The Authors acknowledge the financial support of the National Social Science Foundation of China (07BJY062), the National Natural Science Foundation of China (70603036), and the Dutch Government.

## I. Introduction

The rapid growth of China's economy has led to increasing demand for energy and has given rise to mounting concerns in China about national energy security. The nation's emissions are also becoming a concern of the Chinese Government as well as the rest of the world. In 2006, China imported 350 million tons of oil, accounting for approximately 48 percent of its total oil demand (NSBC, 2007). According to a study by the International Energy Agency, by 2020, 77 percent of China's total oil will be supplied by the international market, and this figure will increase to 80 percent by 2030. Given China's energy security concerns, the search for alternative sources of energy has become a top policy priority of the Chinese Government. Bio-ethanol, with its reputation of being relatively carbon neutral, has been the center of much government attention.

China is now the third largest bio-ethanol producer in the world after the USA and Brazil, respectively. In 2007, China's bio-ethanol production reached 1.33 million tons. Maize is the primary feedstock. Like many countries, China has initiated an ambitious biofuel development strategy and has established high targets for itself. In China's "Middle and Long Term Development Plan of Renewable Energy," annual bio-ethanol production is targeted at 10 million tons by 2020 (NDRC, 2007). To encourage the expansion of the biofuel industry in China, tax reductions, subsidies and other incentive policies have been implemented.

Over the past 2 years there has been rapid development of the biofuel industry in China and other countries, especially in the USA and Brazil. At the same time, agricultural prices have risen rapidly on the international market and in China. In 2007, food prices on the international market increased by 15.6 percent and those in China by 10.8 percent (on a year to year base) (IMF, 2008; NBSC, 2008). Since mid-2007, the monthly growth rates of China's food CPI have exceeded 15 percent. Importantly, the rise in food prices have accounted for more than 80 percent of China's overall price increases over the past 12 months (NBSC, 2008).

The rise in food prices has triggered China's concerns regarding its food security (Huang *et al.*, 2008). Ensuring national food security is a central goal incorporated in China's agricultural policies. China had aimed to achieve self-sufficiency in total grain consumption before the 1990s. Then in the late 1990s, a target grain self-sufficiency rate of higher than 95 percent was set (Huang and Rozelle, 2003). Although China is now a net exporter of food and feed, it runs a large deficit in vegetable oil and soybean. In 2006, China's importation of vegetable oil reached 6.3 million tons, and the import of soybean reached 27.8 million tons, accounting for 60 percent of its total soybean demand (NBSC, 2007). With the rising demand for livestock products, it is expected that China will soon switch from being a maize exporter to being a net importer[1] (Huang *et al*., 2006).

To ease the increasing pressure on food prices, at the end of 2007, the Chinese Government eliminated rebates of value added tax (VAT) for exports of all grains and a set of other processed products, with the intention of discouraging food exports. In January 2008, the Chinese Government took further action, imposing export tariffs of 5–25 percent on the same commodities. With the concern that biofuel expansion might add further pressure on food security, in September 2007, the Chinese Government issued a temporary regulation on biofuel feedstock use. The policy reads that: "biofuel must not compete with grain over land, must not compete with consumers for food, and not enter competition with livestock over feeds, and must not inflict harm on the environment" (NDRC, 2007). In addition, China has prohibited future increases in the use of grain for biofuel production. Instead, it is encouraging the use of sugarcane, cassava, sweet potato, sweet sorghum, and other non-grain crops as its major biofuel feedstocks.

Although well intentioned, it is unclear how such policies can be implemented and whether these policies can really ease the pressure on food prices and food security. If feedstock prices increase in the future with the expansion of the biofuel industry, farmers will increase their production of feedstock at the cost of reducing the production of other crops like rice and wheat, hence adding pressure to agricultural prices. As the Chinese Government is faced with ensuring both food security and energy security, there is a drastic need for careful and rigorous assessment of the effects of promoting biofuels in China. The government must also determine how China should advance its bio-ethanol industry in a sustainable way.

The overall goal of the present paper is to carry out a study of the potential impact of increased bio-ethanol production on agricultural production, food prices, and farmers' incomes in different regions of China. The paper is organized as follows. The next section discusses the development of bio-ethanol production in China and the policies that promote and regulate the development of the bio-ethanol industry. Section III presents the methodology, as well as scenarios that are used to analyze the likely impacts of the use of alternative feedstocks for bio-ethanol production in China. Section IV presents the results of our simulations of the impacts of China's bio-ethanol program on agricultural prices, production and farmers' incomes in different regions of China. We conclude the assessment with a discussion of policy implications.

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[1] Fisher *et al.*, 2005, "Management a successful transition of China's agricultural transition," Report of the Chinagro project to EU committee on the sustainable adaptation of China's agriculture to globalization, International Scientific Cooperation Project, ICA4-CT-2001-10085, IIASA.

## II. Development of China's Bio-ethanol Industry and Related Policies

In the mid-1980s, China launched its national biofuel (including bio-ethanol) R&D program. Investment in biofuel was mainly made through national R&D programs, such as the National High Technology Research and Development Program (also known as the 863 Plan). In 2001, three large bio-ethanol plants using maize as feedstock were established in Heilongjiang, Jilin and Anhui. To reduce the reserve costs and to dispose of the rotting wheat, China built another ethanol plant using wheat as a feedstock in Henan Province in 2004. With the prospect of limited supplies of maize and wheat grain available for bio-ethanol production, China has begun experimenting with the use of other crops to produce ethanol. In 2006, China's government approved a cassava-based bio-ethanol plant in Guangxi Province: this plant commenced operate in early 2008.

Bio-ethanol production in China increased from 30 000 tons in 2002 to approximately 1 330 000 tons in 2007 (CAAE, 2008). Table 1 shows the distribution of the four existing bio-ethanol plants in China and their demands on feedstocks. Given that the rotting wheat in the national reserves had run out, in 2007 all four plants were using maize as major feedstock for bio-ethanol production. The total maize demand for bio-ethanol production was approximately 3.18 million tons. The cassava based bio-ethanol plant in Guanxi Province only started to run in early 2008, so its output of bio-ethanol and feedstock demand is not yet clear, but based on its designed production capacity (200 000 tons per year) and current production technology (7.5 tons of fresh cassava can produce 1 ton of bio-ethanol), we estimate that its annual fresh cassava demand will be 1.5 million tons.

**Table 1. Distribution and Feedstock Use of Bio-ethanol Plants in China in 2007**

| Location | Yield (thousand ton) | Feedstock | Feedstock demand (thousand ton) |
|---|---|---|---|
| Jilin | 380 | Maize | 990 |
| Heilongjiang | 150 | Maize | 330 |
| Henan | 470 | Maize/wheat | 900 |
| Anhui | 330 | Maize | 960 |

Source: CAAE (2008).

To facilitate bio-ethanol production and marketing, China has set up a series of supporting policies (since the early 2000s). The first five-year plan for bio-ethanol, the Special Development Plan for Denatured Fuel Ethanol and Bio-ethanol Gasoline for Automobiles in the Tenth Five-Year (2001-2005), was announced in early 2001. The main goal of the Plan was to experiment with bio-ethanol production, marketing and support measures. To achieve this goal, two policy documents were jointly issued by the National Development and Reform Commission (NDRC) and seven other relevant ministries in 2002 and 2004: the "Pilot Testing Program of Bio-ethanol Gasoline for Automobiles" in 2002 and the "Expanded Pilot Testing Program of Bio-ethanol Gasoline for Automobiles" in 2004 (NDRC, 2002 and 2004). With these policies in place, four bio-ethanol plants were set up, and nine provinces were selected to use E10 oil (gasoline mixed with 10 percent bio-ethanol). In 2005, China issued the Renewable Energy Law, which has been in effect since 1 January, 2006. It is clear from this law that China will forcefully push the development of renewable energy. In June 2007, under the guidelines stipulated by the Renewable Energy Law, the NDRC formulated the Middle and Long Term Development Plan of Renewable Energy. The Plan aims to lower China's dependency on petrol oil imports (the share of imported oil in total domestic consumption) to less than 50 percent by 2020. The annual bio-ethanol production is targeted as 10 million tons by 2020.

To encourage the expansion of the biofuel industry in China, a set of incentive policies has been implemented since 2002. The policies include: mandatory mixing of 10 percent bio-ethanol in gasoline in nine provinces to secure the biofuel market; the 5 percent consumption tax on bio-ethanol being waved and the 17 percent VAT being refunded to the bio-ethanol production plants; and direct subsidy to biofuel plants to ensure they can make an appreciate level of profit. However, in response to the recent increase in food prices and the mounting concerns relating to food (grain) security, in mid-2007, the Chinese Government announced a regulatory policy on bio-ethanol expansion, and stated that it will prohibit grain-based biofuel expansion in the future. Instead, it is encouraging the use of sugarcane, cassava, sweet potato, sweet sorghum and other non-grain crops as its major biofuel feedstocks.

## III. Methodology

A multiregional equilibrium model, the Decision Support System for China's Sustainable Agricultural Development (CHIANGRO), can be used to explain the potential impacts of biofuel development on China's agricultural production, food prices and farmers' incomes. In this section, after a brief introduction of the model, scenarios and assumptions of the simulation are discussed.

## 1. CHINAGRO Model

CHINAGRO is a 17-commodity, 8-region general equilibrium welfare model. The model consists of six income groups per region, with production represented at the county level. For each county, the model includes 28 outputs and a range of 14 farm types involved in cropping and livestock production. The 28 products include most of China's agricultural products, including rice, maize, wheat, sugarcane, oil crops, pork and poultry. Consumption is depicted at the regional level, separately for urban and rural populations, and domestic trade is interregional. Agricultural supply of each county responds to the market prices faced by various farm types in each county. Other farm resources, such as agricultural labor, agricultural machinery, and land, are imposed as fixed constraints in the model. The total area for cultivation and the maximum yield potential on each farm type are based on existing agro-ecological zone assessments. Parameters of labor, fertilizer and animal feed requirements per unit of output are estimated econometrically using agronomic data. Consumers of agricultural products are represented for every income group in each region, and separately for rural and urban consumers, as exercising demand dependent on prevailing consumer prices and income available to them. Additional details of the model specification are described in Keyzer and van Veen (2005).

As is the usual practice in general equilibrium analysis, supply and demand are balanced for all commodities simultaneously through intraregional, interregional and international trade, jointly with price adjustment subject to various policy interventions, such as tariffs and quotas on international trade. The model operates on an annual basis, evaluating solutions under given scenario conditions for selected years. With respect to validation, the welfare model fully replicates for every county and region of China for the 2003 base-year conditions.

## 2. Scenarios and Assumptions

Based on China's plan for bio-ethanol expansion in the Medium and Long Term Development Plan of Renewable Energy, we assume that an annual production of 10 million tons of bio-ethanol will be reached by 2020. Following previous practice, bio-ethanol firms will be located in the main production regions of the feedstock crops used for bio-ethanol, but interregional trade in these crops and in bio-ethanol are permitted in the model to accommodate changes in specialization patterns induced by the scenarios. Also based on current practices in bio-ethanol production in China, we examine bio-ethanol production using the following four alternative scenarios:

Scenario 1 (S1): all 10 million tons of bio-ethanol will be produced using maize as feedstock;

Scenario 2 (S2): all 10 million tons of bio-ethanol will be produced using sugarcane as feedstock;

Scenario 3 (S3): all 10 million tons of bio-ethanol will be produced using tuber crops as feedstock, including cassava and sweet potato;

Scenario 4 (S4): a mixed scenario; that is, we assume 5 million tons of bio-ethanol will be produced using maize as feedstock and that sugarcane and cassava will each produce 2.5 million tons of bio-ethanol.

We compare results from the above four alternative scenarios with the results from the baseline scenario (S0), which serves as a reference and involves no biofuel expansion. The baseline scenario is characterized by: (i) continuation of the current growth rates in non-agricultural sectors, supported by large investments in the manufacturing and service sectors and a considerable outflow of labor from the rural areas; (ii) increased pressure on agricultural land and water availability in densely populated counties as a result of this urban and industrial expansion; (iii) shifts in consumption patterns towards more meat, dairy, and fruit and vegetables resulting from higher incomes in non-agricultural sectors; (iv) continued liberalization of agricultural foreign trade, elimination of farm taxes, technical progress through sustained spending on R&D; and (v) gradual price increases of agricultural prices, particularly for feed grains and meat, relative to non-agricultural price beginning in 2010.

To simplify the analysis and to derive policy implications, we have made several assumptions regarding trade. After simulation of the baseline, we found that China would be a net importer of all three crops (maize, sugarcane and tuber crop) in 2020. To explore the potential impacts in China of ethanol production without additional demand being satisfied through imports, we impose import quotas for all of these three crops under all scenarios, which means the import volumes of these three crops cannot be higher than the import levels under the baseline scenario. We also impose export quotas for the commodities for which China will be a net exporter in 2020. For example, the export of rice was set at 4 383 000 tones, and vegetables at 7807 000 tones. Such quotas admittedly do not conform to WTO regulations. However, the rationale underlying their use is that it is useful to identify the extent to which China is able to satisfy its own feedstock demand for its biofuel production. Moreover, allowing for unrestricted imports would inevitably lead to significant increases in world prices. Hence, the present implementation can be interpreted as an extreme case in which the world market would already be fully committed and have zero supply elasticity.

## IV. Impacts of China's Future Biofuel Expansion

### 1. Impacts on China's Agricultural Prices

Table 2 presents the results for price changes under different scenarios compared with the baseline results. Under S1, the maize price in 2020 is projected to be 74.3 percent higher than in the same year under the baseline scenario. The extent to which other crop prices change depends on the nature of substitution between those commodities and maize. For example, under S1, wheat prices in China increase by approximately 9.2 percent, whereas sugar prices only increase by approximately 4.4 percent. The price increase of maize and other crops will also increase the cost of livestock production. Under S1, the pork price in China will increase by 9.7 percent.

The results of the sugarcane scenario, (S2), suggest that a bio-ethanol program based on sugarcane as a feedstock is not a good choice in China. Compared with the results of the baseline scenario in 2020, the sugarcane price is projected to increase nearly four times (394 percent) in the same year (Table 2). Therefore, the use of sugarcane as a primary feedstock is not likely to occur. The level of price projected implies an extremely high level of government subsidies required to maintain its bio-ethanol program. This high price would lead to an obvious violation of WTO rules. If China does not impose a high import tariff on sugar, most of the extra sugarcane demand would have to be satisfied through imports from the international market, something that might not be feasible as sugarcane (as opposed to sugar) is not a highly traded commodity. Using tuber crop as the primary feedstock source (S3) of China's bio-ethanol production could also lead to higher prices for all agricultural commodities. Compared with the results of the baseline in 2020, the tuber crop price would be 98.8 percent higher under this scenario.

As expected, the impacts of the mixed scenario (S4) on each of the feedstock prices are much weaker than in the previous three scenarios (Table 2). Under S4, three crops (maize, sugarcane and tuber crop) are simultaneously used as feedstock for bio-ethanol production, and the demand pressure on any single crop is consequently eased. The simulation results show that, compared with the results of the baseline scenario in 2020, the prices of maize, sugarcane and tuber crop in China will be approximately 42.2, 78.6 and 23.3 percent higher, respectively. Therefore, even under the mixed scenario of multiple feedstock sources, a bio-ethanol program with a target of 10 million tons of production will create significant incentives for farmers to produce these feedstocks for bio-ethanol production, if prices are allowed through market forces to rise as demand rises.

Whether or not China's domestic prices of maize, sugarcane and tuber crop could increase significantly without large imports of these products is an issue for which further investigation is needed. Answers to these questions require a better understanding of the future development and scope of bio-ethanol programs in the rest of world, particular those in the USA, Brazil, the EU, India, and other major countries, and their impacts on international agricultural prices. If price increases in maize, sugarcane and tuber in international markets due to worldwide bio-ethanol development are less than price increases of these commodities

**Table 2. Impacts of China's Bio-ethanol Development on the Prices of Its Agricultural Commodities in 2020, Compared with Baseline Results (%)**

| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| Rice | 4.2 | 11.8 | 4.7 | 8.0 |
| Wheat | 9.2 | 9.0 | 7.5 | 8.6 |
| Maize | 74.3 | 9.2 | 10.1 | 42.2 |
| Tuber crop | 4.6 | 11.6 | 98.8 | 23.3 |
| Vegetable oil | 5.4 | 9.2 | 2.8 | 5.1 |
| Sugar | 4.4 | 394.1 | 5.1 | 78.6 |
| Fruit | 6.6 | 5.9 | 4.6 | 6.2 |
| Vegetable | 13.1 | 11.1 | 7.1 | 12.1 |
| Beef and mutton | 3.3 | 3.1 | 3.2 | 3.2 |
| Pork | 9.7 | 4.9 | 5.3 | 8.0 |
| Poultry | 9.8 | 4.8 | 6.0 | 8.0 |
| Dairy | 5.8 | 3.1 | 3.5 | 4.7 |
| Eggs | 10.5 | 4.2 | 4.2 | 8.1 |

Sources: Model simulation by authors' compilation.

in China, the above analysis shows that China will have little choice but to increase its imports of feedstock for ethanol production or directly import some amount of bio-ethanol to successfully implement its E10 plan in the future.

## 2. Impacts on China's Agricultural Production

The projected increase in the prices of the three major feedstocks examined will trigger significant increases in the production of these commodities. Table 3 shows the percentage changes in production of different scenarios compared with the baseline results in 2020.

Under S1, maize production in China will increase by 20.8 percent over the baseline, with contributions towards the increase in production from both yield increases in maize and crop substitutions into maize from other crops. Under S2, sugarcane production is projected to increase by 154.3 percent, with all increased production taking place in south China due to the unsuitability of agro-climatic conditions for sugarcane production in other areas. Under S3, tuber crop production will be 43.9 percent higher compared with the baseline results. Under the mixed scenario (S4), production of maize, sugarcane and tuber crops will increase by 9.7, 26.6 and 6.5 percent, respectively. Livestock production will also decline compared with the baseline results, because of the increase in input costs and the

**Table 3. Impacts of China's Bio-ethanol Development on the Production of Its Agricultural Commodities in 2020, Compared with Baseline Results (%)**

| | S1 | S2 | S3 | S4 |
|---|---|---|---|---|
| Rice | –0.4 | –1.8 | –0.7 | –0.9 |
| Wheat | –1.3 | –1.0 | –1.1 | –1.1 |
| Maize | 20.8 | –1.4 | –1.2 | 9.7 |
| Tuber crop | –3.4 | –0.6 | 43.9 | 6.5 |
| Vegetable oil | –3.0 | –0.8 | –2.2 | –2.1 |
| Sugar | –1.8 | 154.3 | –1.9 | 26.6 |
| Fruit | –1.4 | –1.4 | –1.0 | –1.3 |
| Vegetable | –2.0 | –2.0 | –1.4 | –2.0 |
| Beef and mutton | –0.5 | –0.8 | –0.7 | –0.6 |
| Pork | –2.6 | –1.0 | –0.8 | –1.8 |
| Poulty | –2.3 | –0.9 | –0.7 | –1.5 |
| Dairy | –2.6 | –1.0 | –0.7 | –1.7 |
| Eggs | –3.0 | –0.9 | –0.8 | –1.9 |

Sources: Model simulation by authors' compilation.

scarcity of agricultural production resources.

### 3. Impacts on Farm Value Added in Different Regions

Because there are significant substitution effects among commodities and among regions, we also estimate an aggregate measure, the change in net output value or farm value added resulting from the impacts of alternative bio-ethanol programs on agricultural sector. Table 4 shows that different bio-ethanol programs have significant equity implications for farmers in different regions of China.

Comparing the results from all four scenarios, farmers in China would benefit from the development of bio-ethanol, with an increase of farm value added of 3.2–8.1 percent under different scenarios (last row of Table 4). However, the impacts vary significantly among regions and farmer groups. Under all four scenarios, farmers in the crop sector will gain while those specializing in livestock will lose. From a regional perspective, Tibet will be affected negatively under all scenarios, because Tibet is not suitable for feedstock production, and its livestock sector will suffer from the increase in feed prices. However, the effects will be minor. Farm value added in most of the other regions will increase due to bio-ethanol expansion, except in South China under S1.

**Table 4. Impacts of China's Bio-ethanol Development on Farm Value Added of Different Regions of China in 2020, Compared with Baseline Results (%)**

| | S1 | | | S2 | | | S3 | | | S4 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Crop sector | Livestock sector | Total | Crop sector | Livestock sector | Total | Crop sector | Livestock sector | Total | Crop sector | Livestock sector | Total |
| North | 15.8 | –9.3 | 5.5 | 2.2 | –0.3 | 1.2 | 12.5 | –2.3 | 9.7 | 11.9 | –5.2 | 4.9 |
| Northeast | 34.2 | –7.9 | 13.6 | 11.5 | –0.8 | 5.5 | 13.2 | –1.8 | 8.7 | 21.8 | –4.4 | 9 |
| East | 3.8 | –1.3 | 2.4 | 2.4 | –0.1 | 1.5 | 7.4 | –0.8 | 8 | 4.1 | –0.3 | 2.6 |
| Central | 2.8 | –1.8 | 1.3 | 6.7 | –0.3 | 3.7 | 6.6 | –1 | 6.5 | 4 | –0.5 | 2.1 |
| South | 1.7 | –3.7 | –0.5 | 31.6 | –1.8 | 18.3 | 6.5 | –1.3 | 6.6 | 8.2 | –2.2 | 4.1 |
| Southwest | 8.2 | –14.3 | 0 | 12.3 | –0.7 | 7.6 | 10.5 | –2.1 | 9.4 | 8.8 | –7.9 | 2.7 |
| Tibet | 2.7 | –6 | –3.3 | 1.3 | –0.8 | -0.2 | 1.7 | –2.1 | -0.5 | 3.4 | –3 | –1.1 |
| Northwest | 15.9 | –4.1 | 7.7 | 15.2 | –1.5 | 8.3 | 9.9 | –2.1 | 8.2 | 13 | –2.5 | 6.6 |
| National | 9.3 | –6.1 | 3.2 | 11.7 | –0.7 | 6.7 | 9.6 | –1.6 | 8.1 | 10.2 | –3.4 | 4.1 |

Sources: Model simulation by authors' compilation.

## V. Conclusions and Policy Implications

China considers the development of bio-ethanol to be an important tool to improve its national energy security, to reduce negative environmental impacts, and to stimulate agricultural development. The rapid growth of the Chinese economy has led to a rising demand for energy from international markets and increasing concerns for its energy security. Although China's current bio-ethanol production based on grain is only approximately 1. 3 million tons, it has begun to implement an ambitious plan to expand its bio-ethanol production to 10 million tons by 2020.

To gain some insight into the impact of China's bio-ethanol development on its agricultural economy, a quantitative analysis is conducted using the CHINAGRO model to test the feasibility of producing 10 million tons of ethanol under four scenarios: a maize scenario, a sugarcane scenario, a tuber crop scenario, and a scenario using a mix of the three crops. The potential impacts of these alternative bio-ethanol development programs on agricultural production, food prices and farmers' incomes are assessed.

The results show that the increase in demand for feedstock to produce bio-ethanol will lead to large increases in the prices of these feedstock crops. The increase in price triggers a significant rise in production of these crops and a shift in the crop production structure in China. The gain in the production of the commodity targeted in a given scenario is partly obtained via higher yields but more significantly by substitution away from crops that are not directly associated with the bio-ethanol program (e.g. wheat and rice). The study also reveals that bio-ethanol competes with animal feed and that the price increases for animal feed significantly lower farmers' incomes from livestock production. More importantly, the impacts of alternative bio-ethanol programs on farmers' incomes in different regions vary substantially across regions.

The results from this study have potentially important implications for China's future bio-ethanol development, food security, and income distribution among regions and farmer groups. First, the viability of different crops as feedstock for bio-ethanol requires careful analysis prior to a large-scale expansion of China's bio-ethanol program. A mix of several alternative feedstock sources for bio-ethanol should be explored. An exclusive, or near exclusive focus, on sugarcane or cassava is not possible without substantial imports of these commodities.

Second, there will be substantial financial implications of promoting a large scale bio-ethanol program in the future. Based on our personal interviews, currently, approximately 40 percent of total crop-based biofuel production costs are covered by government subsidies. Although some bio-ethanol production costs could be reduced with improvements in technology and production efficiency, the costs of feedstock will also increase significantly as the prices of feedstocks rise with the expanded use of these crops for bio-ethanol production. The level of subsidies will of course also depend on the trend of oil prices in the international markets.

Third, with respect to national food security, if feedstock is sourced from maize or tuber crops, such as cassava and sweet potato, the greatest impacts are on livestock production. National food security might also be affected through the large price increases in maize and sugar, although these price increases would certainly be dampened by loosening the constraints imposed on import quantities. To alleviate the possible negative impacts of biofuel on food security, government supports should focus more on productivity enhanced investments: for example, on increasing investment in energy crop R&D and increasing investment in biofuel processing technology research.

Fourth, the bio-ethanol program has some potential as a mechanism through which rural households can increase their farming incomes. China is an interesting case because all rural households have access to land and nearly all rural households sell a portion of their agricultural products in the market. The national average farm size is 8.8 mu, or 0.59 ha, ranging from less than 0.3 ha in south China to approximately 0.8 ha in the central region and more than 1 ha in northeast China (MOA, 2007). Farmers in maize production regions, particularly in northeast and north China, can increase their farming incomes as the bio-ethanol program is expanded.

Last, but not least, given the trade-offs between grain security and energy security, use of other feedstocks, particularly those utilizing second generation technologies, should continue to be researched. However, the use of feedstock such as crop residues should be considered carefully because of its potential use as livestock feed and in sustainable crop production management practices.

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