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Global biofuel production and poverty in China

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ABSTRACT

This study assesses the future impacts of biofuel production from the world's major biofuel producers (the US, Brazil and the EU) over the next decade on global markets and the resulting spatial implications on income distribution and agricultural production in China. Rising global commodity prices arising from either positive market conditions for biofuels or government mandates on biofuel production levels, are transmitted, albeit imperfectly, into China's domestic food economy. For those crops that are being used for feedstocks internationally (maize) or are close substitutes for feedstocks (soybeans), production rises sharply. Imports also fall significantly. Such dynamics help China to realize its self-sufficiency goals more fully. Another unintended benefit of the increase in global biofuel use is the impact on Chinese income distribution. China's farmers—especially the poor—benefit from biofuels.

1. Introduction

Biofuel production has increased five-fold over the last two decades due to policy interventions and changing relative energy prices [1]. One of several motivations for the promotion of biofuels was to increase returns to farmers, and agricultural commodity prices have indeed risen significantly since the fall of 2006 [2,3]. This price increase, however, has triggered concerns from governments and development agencies about implications for food security and poverty around the world [4–10]. It has been estimated by the World Bank [11] that over 44 million people fell below the extreme poverty line of $1.25 per day due to the change in food prices during the second half of 2010.

The effects of biofuels and the possibility of higher commodity prices caused by their emergence, however, may not be all bad for developing countries and the poverty that they face. While regions with a high share of food imports are likely to suffer, other developing countries with a higher degree of food self-sufficiency could benefit. Similarly, within a given country, farmers that are net sellers should gain, especially if they own land. For example, the above World Bank [11] estimate accounts for 24 million net food producers who escaped extreme poverty with the higher prices for their produce. Higher prices may also lead to a higher demand for labor and enhance income for others that are not farmers in rural areas.

The distributional issues surrounding biofuels are of particular concern in China. China was prepared to become a major global producer of biofuels. Its investment in four large-scale ethanol plants in the early 2000s resulted in it becoming the third largest producer of ethanol in the world by 2007. However, future expansion plans were derailed by the large increase in commodity prices and the concern that the enhanced demand for feedstock crops from higher biofuel levels would push domestic food prices unacceptably high. The worries over national food security from biofuels are not unique to China, but the structure of its agricultural sector and the nature of its income distribution make it a particularly interesting country to assess the equity implications of the food versus fuel debate for other regions [12–14]. The Chinese farm sector is large and is made up almost exclusively of small producers who suffer from low incomes. Poverty in China is truly a rural phenomenon with the poorest most likely to be crop farmers. Thus, biofuels have the potential in this country to raise the returns to farmers and thus potentially income but it is unknown if such an increase will occur or if such an increase would alleviate poverty levels.

There are few systematic efforts to track the pathways of global biofuel production to specific developing countries and down to the household level. There are a number of high quality modeling efforts that are concerned with biofuels [15–21]. However, due to shortcomings such as a regional rather than global assessment (i.e. US or EU), or a partial rather than general equilibrium focus, or no explicit accounting for a biofuels supply and demand sector, these models do not sufficiently capture the complexities of global

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biofuel and food markets. Furthermore, there are no specific modeling efforts that seek to follow biofuels impacts from developed countries all the way to the doors of the poorest of the poor—either consumers or producers—in a developing country.

This study seeks to assess the future impacts of biofuel production from the world's major biofuel producers (the US, Brazil and the EU) over the next decade on poor households in one country—China. Using two modeling platforms created to account for: (a) the global interactions of regional biofuel and food markets; and (b) the supply, demand and trade inside China in response to shocks in world markets, the analysis aims to provide answers for the following questions. First, how will the rise in demand for biofuels affect food prices, production and trade at a global level? Second, how will the development of global biofuels affect prices, production, trade and the unskilled wage in China? Thirdly, how will these global and domestic market changes from biofuels affect producers and consumers in different segments of China's food economy? Answers to the above questions will be used to discuss policy recommendations regarding the development of economically and socially sound biofuels program in the world and in large, developing countries like China.

To meet our objectives, the paper is organized as the follows. The next section provides an overview of China's food economy and the role of biofuels in the nation's agricultural strategy. The third section discusses the methodology developed for assessing the full impact pathway of biofuel development from world markets to the border of China (and other nations in the world) and from the border of China to the household level, disaggregated by income level, province and crop type. The fourth section presents the results of our modeling efforts including the impacts of alternative biofuel development scenarios on world food production, trade and price as well as the effects on different types of Chinese households. The last section concludes with a brief discussion of the policy implications of the study's findings.

2. Background

2.1. Poverty and farming in China

China's economy has experienced remarkable growth since economic reforms were initiated in the late 1970s. The annual growth rate of gross domestic product (GDP) was nearly 10% between 1979 and 2009 [22]. The policy shift also helped more than 230 million rural residents escape poverty over the past two and half decades; the absolute level of poverty fell from 260 million in 1978 to less than 30 million in 2002 [22]. The incidence of rural poverty has fallen from 32.9% in 1978 to less than 3% in the mid-2000s if measured by China's official poverty line or approximately 10% if based on the World Bank's "one-dollar-per-day" poverty line. While the fall represents a significant improvement in overall living standards, there are still a large number of Chinese people living in extreme poverty and, importantly for this paper, the vast majority are in rural areas. According to the World Bank [23], only 1–3% of those below the poverty line live in urban areas. Poverty in China is truly a rural phenomenon.

The income gaps between regions, between urban and rural, and between households within the same location have increased steadily since the middle of the 1980s [24]. The ratio of urban to rural incomes exceeded 3.3 in 2009, which was up from 1.8 in 1984 [22]. Rural poverty rates based on the National Poverty Line range from 1.2% in the more urban South region to 5.3% in the more rural Northwest region of China. In addition to growing disparities between urban and rural as well as across provinces, income differences have also risen within rural areas as indicated by the Gini coefficients of 0.24 in 1980 versus 0.35 in 2000 [22].

Table 1
The share of farmer's income from agriculture by different income groups in China, 2005.

Income group[a]	Total income (Yuan/person, year)	Share of agricultural income (%)	Share of crop income (%)
National Average	3522	49.5	39.1
Income group 1 (under poverty [a])	757	59	57
Income group 2[b]	1659	57	47
Income group 3[b]	2477	53	42
Income group 4[b]	3421	50	39
Income group 5[b]	5048	44	32
Income group 6[b] (highest income)	9253	28	16

Source: Estimated based on rural income and expenditure survey conducted by National Bureau of Statistics of China in 2005.

[a] The group under poverty includes all households with per capita income of less than 1196 yuan in 2005, which accounted for about 10% of rural population.

[b] The groups 2, 3, 4, 5 and 6 accounted for about 20%, 20%, 20%, 20% and 10% of rural population in 2005.

The poorest in rural areas of China are also likely to be farmers, particularly crop farmers. The share of income from agriculture for farm households below the poverty line in China is approximately 59% whereas it is less than 50% on average for all rural residents (Table 1). The majority of income (57%) is from cropping for those individuals in the poorest decile while the national average is less than 40% across all rural residents. Consequently, increasing revenue from crop production positively affects the poorest rural households and thus can reduce China's growing income disparity.

Enhancing crop income and thereby its positive effects on rural poverty are constrained by the lack of productivity growth in Chinese agriculture since the late 1980s [25]. Rising input levels in many areas of China and diminishing marginal returns mean that increasing inputs will not provide large increases in output [26]. Water shortages and increasing competition from industry and domestic use for the remaining scarce supplies do not provide much hope for large gains in area or yields from new irrigation expansion. Trade liberalization could also curtail rather than stimulate income growth in rural areas of China. Agriculture was at the center of discussion of China's entry into the WTO particularly given the general perception that the actors in the rural economy are particularly vulnerable to opening competition with the agricultural economies elsewhere in the world [27,28].

In the future, many have predicted that almost all gains will be productivity driven and these will have to come from second- and third-generation Green Revolution technologies [25]. Although there are many potential factors that will create stresses for farmers trying to grow crops and earn profits in the coming years, biofuels is one area that holds the promise of a gain for Chinese farmers. Will biofuels be able to raise the price of crops earned by farmers? If so, will the incomes of farmers rise? Finally, and most fundamentally for a paper interested in the poverty effects, how would such price increases affect the poor? These questions will be the focus of the analysis below. First, however, after we briefly discuss world biofuel production and policy, we present a short discussion of China's own biofuels policy to see if the rise in prices from biofuels should be expected to come from world markets alone or if China's own investments into biofuels will affect the domestic price of crops.

2.2. Global biofuel production

Biofuels have been produced commercially for over a generation with development programs starting in the middle of the

1970s in response to the OPEC-driven increase in fuel prices and the subsequent concern about domestic energy security. However, production was limited with only 420,000 tons of ethanol processed in 1975 and biodiesel was not available, as commercial manufacturing did not begin until the early 1990s. By 2000, 15 million tons of ethanol was being produced and 0.8 million tons of biodiesel but this was just the beginning of a decade of rapid growth for the sector. Biofuel production reached 80.1 million tons in 2009 with ethanol (biodiesel) levels increasing by approximately 5 (17) times over the decade. Biofuel production is concentrated largely in the United States, Brazil and the European Union. The rapid growth across these regions has been spurred partially by the profitability for production, which is tied to the relative cost of crude oil and feedstock prices, but largely by government policies [29–31].

Initiatives used by governments to support the emergence of biofuels include incentives and regulations. For example, the United States, which now produces more than half of the world's ethanol, began its promotion of ethanol production with the Energy Tax Act of 1978. Biofuel producers were granted full exemption of the federal gasoline excise tax when they produced gasoline blended with 10% ethanol resulting in an effective subsidy of US 40 cents per gallon of ethanol [32]. American blenders of ethanol have also been provided with a tax refund per gallon and protection through an import tariff on ethanol from outside NAFTA [32,33]. The continued growth in US ethanol production was ensured through the "Energy Independence and Security Act" passed in 2007 which established ambitious volumetric mandates on future biofuel use [34].

Brazil produced approximately one-third of the world's ethanol in 2009. The Brazilian government stimulated the growth of its biofuel sector largely by inducing consumers to choose biofuels as a fuel substitute. Programs included the National Fuel Ethanol Program which promoted the availability of ethanol at most gasoline stations and mandated the manufacture of flexible fuel cars capable of using pure gasoline, E25 or pure bioethanol. Through this stimulus along with mandates on the blending ratio of ethanol with gasoline and differential tax rates, the Brazilian government seeks to have ethanol production reach 31 million tons in 2012 and 38 million tons in 2016 [35].

The EU produces approximately three-quarters of the world's biodiesel mostly using rapeseed as its feedstock crop. While the decision to support the production and use of biofuels was left to Member States, the 2003 Biofuel Directive of the EU suggested a target of 5.75% of total petrol and diesel fuel used for transport be provided by biofuels. In the mid-2000s, the EU began to direct its Member States to set up the necessary legislation to ensure compliance as well as provide tax concessions, crop payments, and allow for the use of tariffs for the promotion of biofuel use [31,36].

China appeared ready to become a major player in the biofuel sector in the last decade. Four large-scale, state-owned ethanol plants were constructed in 2001 in Heilongjiang, Jilin, Henan, and Anhui provinces. Six years later, ethanol production reached 1.35 million tons making China the third largest producer of ethanol in the world with much of it concentrated in the four plants. As in the major biofuel producing countries, the growth was spurred by government policy. Investment in R&D and technology development was provided, national standards for denatured fuel ethanol and bioethanol gasoline for automobiles were implemented, consumption tax exemptions were given, and a subsidy for maize used for ethanol was used. Most importantly, the central and local governments jointly provided a subsidy to ensure a minimum profit for each ethanol plant.

With the experience gained from the first phase of its biofuel policy support, China was set to expand its biofuel program in the mid-2000s with new investments proposed and new production targets established. The planned expansion coincided with the rise in agricultural commodity prices and debates arose surrounding food versus fuel, food security versus energy security, and high prices versus low prices [37]. Indeed, a paper by Qiu et al. [38] suggested that domestic food prices would rise if China expanded ethanol production. In 2007, policy makers clearly came down on the side of food by announcing that the four existing ethanol plants were prohibited from expanding and no more cereals would be allowed for use as ethanol feedstocks beyond those currently allocated. China's drive to become a major biofuel producer had stalled. Hence, any impact of the emergence of biofuels on China's producers in the coming years will necessarily come through international markets.

3. Methodology: modeling global trade and China's domestic food economy

In this section we have four major tasks. The first is to describe the approach used in this study to estimate the agricultural prices at China's border stemming from changes in global biofuel production under alternative price and policy scenarios. The second task is to describe the model of China's domestic economy and how we link this to the global model and to a database that will allow us to measure the impact on different types of households (and different regions of the country). The third task is to describe how the global model is linked to the China domestic model. Finally, we describe the major biofuels scenarios that are used in the paper.

3.1. Global trade model and modeling biofuels

The impacts of biofuel development on global agricultural markets and the rest of the economy are assessed based on the Global Trade Analysis Project (GTAP) platform, which is multi-country, multi-sector computable general equilibrium model [39]. GTAP is designed to account for the direct and indirect feedback effects of policies in a global context [40]. Linkages between biofuel production, energy and global agricultural markets can be captured within GTAP and the impacts tracked from world markets to specific countries or regions. To carry out the impact analysis, we have made a number of key modifications and improvements to the standard GTAP model.

First, the key biofuels feedstock crops are split from the broad categories where they currently reside so that they are represented explicitly in the model database. The standard GTAP database includes 57 sectors of which 20 represent agricultural and processed food sectors. Despite the relatively high level of disaggregation, many of the biofuel feedstock crops are aggregated with non-feedstock crops. For example, corn is aggregated with other coarse grains and rapeseed is part of a broader oilseeds category. The feedstock crops are disaggregate using a "splitting" program (SplitCom) developed by Horridge [41] along with trade data from the United Nations Commodity Trade Statistics Database (UNCOMTRADE) and production and price data from the FAO.

Second, the standard GTAP database does not have a biofuel sector so we created four new industrial sectors for production activities associated with biofuels: sugar ethanol, corn ethanol, soybean biodiesel and rapeseed biodiesel. The manufacturing of these four biofuels depends on the main feedstocks plus capital and labor, which are inputs also used in crop production. Consumers in the model are allowed to substitute between biofuels and fossil fuels, and since biofuel production uses crop sector outputs for inputs, an explicit link between agricultural and energy markets is thereby created.

The agriculture and energy market linkages established through the biofuel sectors were accounted for by introducing energy-capital substitution relationships that are described in the GTAP-E (energy) model, which is widely used for the analysis of energy and climate change policy [42]. The substitution between biofuels and fossil fuel is incorporated into the structure of GTAP-E using a nested CES function between biofuels (ethanol and biodiesel) and petroleum products in a similar way to the approaches taken by others who have added a biofuel sector to the GTAP-E model [16,43]. The elasticity of substitution between fossil fuel and biofuels is an important element tying energy prices and food prices.

Third, the standard GTAP model only captures multi-input and single-output production relationships and does not account for multiple outputs. However, biofuel production generates important by-products, such as dried distillers grains and soluble (DDGS) and biodiesel by-products (BDBPs), that can serve as cost-effective ingredients in livestock rations. These by-products can subsequently reduce the demand for feedstocks and dampen the price increase associated with an increase in biofuel production. The production of DDGS and BDBP also generates a significant share of the total revenue stream for the biofuel industry [21]. A constant elasticity of transform (CET) function is adopted to allow for the optimization of output between biofuel and its byproducts.

An additional modification to the basic GTAP framework is the means of allocating agricultural land across crop uses. An increase in biofuel production will increase the demand for feedstock crops but the feasibility of changing land use from one crop to another may differ significantly by type of land. We use an approach similar to that used in Banse et al. [15] to capture the different degrees of substitutability between agricultural land uses. Unlike the Banse et al. [15] study, however, we do not allow for an endogenous adjustment of total land supply as we do not have either necessary information on availability of new land for agricultural production or the nature of the response of land supply to shifts in land and agricultural prices.

3.2. CAPSiM: China domestic partial equilibrium food economy model

In order to evaluate the impact of global biofuel development on China's agriculture and poverty, an analytical framework has been developed using the Center for Chinese Agricultural Policy (CCAP)'s Agricultural Policy Simulation and Projection Model (CAPSiM). CAPSiM was developed out of need to have a framework for analyzing policies affecting agricultural production, consumption, price and trade at the national level for China. CAPSiM is a partial-equilibrium, agricultural multi-market model with econometrically estimated elasticities. Both demand and supply elasticities change over time as income elasticities depend on the income level and cross-price elasticities of demand (or supply) depend on the food budget shares (or crop area shares).

Details of CAPSiM can be found in Huang and Li [44] and Chapter 6 of the International Agricultural Science and Technology Global Assessment [45]. The baseline scenario assumes that the average annual GDP growth rates in 2006–2020 will reach 9.2% but this rate declines over the period from 10.8% in 2006–2010 to 8.0% in 2016–2020. Similarly, the average population growth, which is 0.49% between 2006 and 2020, slows gradually over the projected period of analysis. Therefore, the average annual per capita GDP growth rate is assumed to remain at 8–9% until 2020. This growth rate implies that China's assumed real per capita GDP will rise from 16,548 yuan in 2006 to 53,275 yuan in 2020. Using 2006 official exchange rates, the real per capita GDP increases in CAPSiM from US$ 2078 in 2006 to US$ 6692 in 2020, which would put it at the level of a middle-income country in 2020. On the production side, the key CAPSiM assumption is that agricultural productivity in China will continue at the rate it has over the past 14 years (2% annually), which is similar to the value used in other models [27,46].

Because the analysis based on the original CAPSiM framework can only be done at national level, the original model has to be modified so that the national impacts are disaggregated into household production, consumption and poverty effects for different income groups at the provincial level. To do this, national prices are transmitted to each region (province) and various households within each region. Each group of households in each region change their production and consumption of each commodity in response to the local prices based on their production and consumption elasticities, which differ by region and household groups. Consequently, the impacts of policy change can be assessed simultaneously at both the national and regional (provincial) levels, and across different income groups.

3.3. Linkages between global and chinese models

The method to properly link GTAP and CAPSiMis crucial to capturing the impacts of global biofuel developments on China. The consistency of initial databases between the two models was carefully checked and some modifications made to ensure the comparability [25]. The price changes from GTAP are transmitted to CAPSiM according to method developed by Horridge and Zhai [47]. Further details on the data and operational processes linking GTAP and CAPSiM are described by Huang et al.[25].

3.4. Scenario formulation

The models are simulated under three scenarios regarding biofuel production levels. Since the main aim of this study is to assess the impacts of global biofuel development on the world food economy (especially how the world food economy affects China), we assume for the "Reference Scenario" that global biofuels production does not expand beyond 2006. Thus, ethanol production is 15.9 million tons for the US, 14.7 million tons for Brazil, and 1.5 million tons for the EU while biodiesel production is 4.9 million tons for the EU and 0.8 million tons for the US.

The "Market Scenario" assumes that only market forces drive any growth in biofuels from the base scenario. Whether biofuels will expand without policy intervention depends critically on the assumed energy price and the ability to substitute between biofuels and fossil fuels. Favorable conditions are assumed for both variables under the "Market Scenario". The oil price, which directly affects the returns to biofuel production, is set at US$120 per barrel. Although relatively high, it is similar to projections from several other studies [48–50]. The elasticity of substitution between biofuel and petroleum products determines the ease at which one fuel can be substituted for another and thus the influence of energy prices on the profitability of biofuel production. While historical estimates of this elasticity are between 1.0 and 3.0 [16], a value of 10 is assumed in the model to reflect the growing infrastructure investments, such as flex-fuel vehicles and fuel stations providing both biofuel-based and petroleum-based fuels that will make it easier to switch between fuels.

The "Mandate Scenario" forces the model to produce at least enough biofuels to meet the country-specific targets for biofuel production in 2020. These mandated levels for ethanol production are 49.1 million tons in the US, 43.2 million tons in Brazil, and 21.0 million tons in the EU. Biodiesel production is targeted at 46.4 million tons for the EU and 6.9 million tons for the US. These target levels are the minimum level of production and more maybe produced within each region depending on the profitability of production. However, the returns to biofuel production are reduced in comparison to the market scenario so that the effect of the mandates can be more clearly illustrated. The energy price is assumed to stay at the 2006 price of US$60 per barrel [51] and the elasticity of substitution between fuels is lowered to 3 from 10 based on historical estimates [16]. Huang et al. [52] assess the effects of alternative assumptions on energy prices and the elasticity of substitution between biofuels and fossil fuels.

4. Results

In this section, we begin by first examining the effect of the emergence of biofuels on the global production of biofuels and (more importantly) on the price, production and trade of feedstocks. This second subsection details how those global changes in prices and trade patterns affect farmers by region and income group in China.

4.1. Global impacts—biofuel and feedstock sectors

The extent to which biofuel production grows over the next decade depends on the combination of policy, energy price, and the nature of the substitutability between biofuels and petroleum-based transport fuels (see Table 2). Without government mandates and low energy prices, ethanol production rises by 46% in Brazil and 22% in the US from 2006 levels while biodiesel increases by 12%. However, production levels increase beyond the government mandates with a high price of energy and a high value for the substitution of elasticity. For example, US mandates call for a 209% (763%) increase in ethanol (biodiesel) production by 2020 but actual production with favorable market conditions will far exceed this government minimum and will increase by 724% (814%). While favorable conditions for biofuel production are largely dependent on energy prices, the elasticity of substitution also plays a role. If the value of this parameter is low and energy prices are high, then US ethanol production increases by 225% as opposed to 763% when it is high. Thus, the easier it is to substitute between biofuel transport fuel and petroleum-based transport fuel, the greater the returns to the biofuel sector and the higher the output levels.

Policy determines biofuel production except in a world characterized by higher energy price and high substitutability between biofuels and gasoline. Especially with low energy prices, biofuel producers will not come close to meeting the requirements set by their respective governments unless mandated to do so. The effect of policy on production levels is particularly evident for biodiesel. For example, under low energy prices and low substitutability, US (EU) ethanol production increases by 763% (847%) over the time period with policy mandates versus 12% (39%) under a market scenario.

The impacts of biofuels on the production, prices and international trade of agricultural commodities are closely related to the growth rate of biofuel production (Table 3). If biofuel production is constrained to be no greater than 2006 levels (reference scenario), then agricultural commodity markets revert back to the long-term trends evident before the price boom in 2006. Real price declines as output growth outpaces the increase in demand with the excess supply dumped onto the global market. For example, US corn price drops by 14.6% while supply increases by 32.8% and exports go up by 88.1% if biofuel production is fixed at 2006 values. The negative impact from stalling the biofuel sector on other feedstock markets is even larger than with US corn.

The influence of biofuels on agricultural markets is highlighted by comparing the above results for the reference scenario to the two other scenarios in Table 3. Preventing the continued rise in the prices of agricultural commodities will require either preventing energy prices from escalating or removing government mandates on production requirements. Assuming higher energy prices and easy substitution between biofuels and fossil fuels, the large increase in biofuel production (see Table 2) results in large increases in price (see Table 3). For example, the prices for US corn and EU rapeseed rise by approximately 50% in 2020 as compared to the reference scenario (Table 3). However, this rise in prices is not coming from reduced supply since production rises sharply (54% for US corn and 94% for EU rapeseed). Demand from the biofuel plants is strong enough that domestic users procure enough of the output that exports fall sharply.

The continued strength in agricultural commodity markets is projected to increase even if market conditions for biofuel productions are unfavorable provided the mandated increases in production remain in place. While the effects are tempered in comparison to the market scenario, prices and supply also increase in the mandate scenario and exports fall. The dampening impact is due to the smaller projected increase in biofuel production levels with the mandates under less than favorable market conditions for biofuel production. In summary, the increases in biofuel supply due either

Table 2
Percentage increase in biofuel production increase in 2020 from 2006 levels for USA, Brazil and EU under alternative scenarios.

Fuel	Region	Energy price[a]	Substitution elasticity[b]	Policy scenario: Market	Policy scenario: Govt mandate
Ethanol	USA	Low	Low	22	209
			High	5	209
		High	Low	225	209
			High	724	724
	Brazil	Low	Low	46	194
			High	34	194
		High	Low	193	194
			High	290	290
Bio-diesel	USA	Low	Low	12	763
			High	−20	763
		High	Low	237	763
			High	814	814
	EU	Low	Low	39	847
			High	35	847
		High	Low	313	847
			High	978	978

[a] Low energy price is US$60 per barrel for crude oil and the high energy price is US$120 per barrel.
[b] The values assumed for elasticity of substitution between biofuels and fossil fuels is 3 for the low scenario and 10 for the high scenario.

Table 3
Percentage change in biofuel feedstock prices, production and export in USA, Brazil and EU under alternative scenarios stemming from biofuel production changes.

Scenario	Variable	USA Maize	USA Soybeans	Brazil Sugar	EU Rapeseed
Reference [a]	Price	−14.6	−11.6	−20	−17.3
	Production	32.8	31.7	17.5	28.9
	Export	88.1	48.3	269	294.5
Market [b,c]	Price	49.6	24.2	83.7	50.6
	Production	54	5.7	147.1	94.1
	Export	−24.5	−14.5	−95.5	−87.5
Mandate [b,d]	Price	15	12.5	38	33
	Production	17	8.5	95	81.6
	Export	−16.6	−13.3	−65.2	−62.8

[a] Percentage change from 2006 to 2020.
[b] Percentage change from reference scenario.
[c] Assumes a high energy price and a high elasticity of substitution between fossil and biofuels.
[d] Assumes a low energy price and a low elasticity of substitution between fossil and biofuels.

to the processors seeking to increase profits or meeting government requirements is projected to have significant impacts on global markets for biofuel feedstocks.

4.2. Chinese impacts

4.2.1. Price, production and trade of chinese agricultural goods

The changes in global feedstock markets resulting from the increases in biofuel production impact China's food economy even though its own biofuel sector stagnates after 2010. The percentage changes in domestic price, supply, and trade (exports and imports) for most agricultural commodities are listed in Table 4. Feedstock markets in China react in a similar manner to global markets from the increase in biofuel production. Maize price in China rises by 11.0% under favorable market conditions despite supply increasing by 4.8% (9.7 MT) and net imports falling by around 70% (10 MT) compared to the reference scenario. While this rise in price is significant, it is less than the approximate 50% increase in the world market price. Such a gap between the world market price and the domestic price of a specific country (in this case China) is common and expected—both in reality and when modeling with GTAP. Frictions, such as tariff barriers, non-tariff barriers, and differences in preferences, almost always keep price shocks from moving fully from world markets to domestic markets [53]. Because of this imperfect pass-through, only about a quarter of the maize price movement on world markets occurs in China.

The continued growth of ethanol in the US and Brazil and biodiesel in the EU also affects the price of other commodities in China. Soybean prices in China rise by 12.1% under favorable market conditions, which is more comparable to the global price increase of 24% since the transmission rate between world markets and China's market is higher for soybeans than maize. Again, as in the case of maize, the rise in the price of soybeans and other oilseeds occurs with a rise in production (1 MT for soybean and 0.325 MT for other oilseeds) and a fall in net imports. The price and supply increases for these biofuel feedstock crops under the market scenario are cut in approximately half if global biofuel production only reaches the mandated levels set by governments.

The price of all other crops are also predicted to rise, although not to the same extent as maize and soybeans, due to the general tightness of agricultural inputs and other resources in world markets. The impact on crop production in China is mixed but typically small. For example, the rise in the supply and net exports of rice is invariably small and occurs because China has a comparative advantage in rice production globally and there is not much competition for resources between rice and the feedstock crops. In contrast, the supply of all livestock types falls. Although the price of livestock rises, the price increase is less than the rise in the price of feed, which is the main input into the livestock production process. Therefore, while the emergence of biofuels raises prices to certain crops unambiguously, especially the feedstock crops, such as maize, and increases production, this impact is not universal across crops. The production/trade effect on some commodities is positive and on other commodities is negative.

4.2.2. Regional market changes

The 9.7 million MT increase in Chinese maize production by 2020 predicted under the market scenario is not spread equally through the country. The largest production effects are found in the maize belt provinces in the Northwest and North parts of China with production rising between 90 and 160 kg per household (Fig. 1). Producers in Northwestern and Southwestern China also increase production but at a smaller rate—between 30 and 90 kg per household. The same pattern holds in the case of soybean production but with the impacts concentrated even more spatially (Fig. 1). The higher soybean production per household occurs largely in the soybean-producing regions of China, which are the Northwest region and the provinces of Shanxi and Anhui. The national average increase in yield of 1.71% for maize and 1.76% for soybeans relative to the baseline is due to more intensive input use. These moderate yield increases are feasible given the 2006 yields for these crops are less than 60% of the yields in the United States [54]. It is important to note that many of China's poor live and farm in the provinces where the increase in feedstock production from the global biofuel developments is projected to occur.

The decline in Chinese livestock production stemming from the rise in feedstock prices varies regionally as in the case of cropping. The largest declines in hog production occur in Sichuan and Chongqing followed by the Southwest and South China, while hog numbers per household change little in the Northwest and North (Fig. 1). Similarly, the reductions in poultry supply are concentrated in the coastal provinces and the Northeast, which are the traditional poultry production regions (Fig. 1). These regions with the largest negative impacts on livestock production tend to have

Table 4
Percentage change in domestic market price, output and trade under market and mandate scenarios in 2020 relative to reference scenario (biofuel at 2006 levels).

Crop	Market scenario[a]				Mandate scenario[b]			
	Price	Output	Export	Import	Price	Output	Export	Import
Rice	2.0	0.1	8.2	−7.5	1.2	0.1	2.8	−4.1
Wheat	3.4	−0.1	10.7	−10.8	2.0	0.0	5.7	−6.2
Maize	11.0	4.8	58	−70.5	5.1	2.1	10.9	−32.0
Other grain	2.7	−1.5	17.4	−17.8	1.6	−0.7	9.4	−9.1
Soybean	12.1	5.4	15.9	−7.8	6.8	3.2	5.7	−4.0
Other oilseed	9.2	3.7	28.3	−31.1	7.5	3.3	21.6	−27.2
Cotton	0.0	2.9	−1.8	−3.3	3.8	1.2	−0.1	−1.4
Sugar	3.8	1.2	5.2	−6	2.5	0.1	−3.0	−1.7
Vegetable	1.4	−0.3	16.7	−9.3	0.9	−0.2	7.7	−6.0
Fruit	1.6	−0.2	31.6	−17.2	1.0	−0.1	14.8	−11.6
Pork	3.5	−1.9	−1.4	1.6	1.7	−0.9	−0.4	0.4
Beef	2.7	−1.2	0.6	0.1	1.3	−0.6	0.1	−0.3
Mutton	2.4	−0.8	1.1	−0.5	1.2	−0.4	0.3	−0.5
Poultry	3.7	−2.2	−2	2.5	1.9	−1.1	−0.7	0.8
Eggs	3.2	−1.5	−0.8	1.4	1.7	−0.7	−0.2	0.4
Milk	1.6	−1.3	1.5	−0.7	0.9	−0.6	0.9	−0.8
Fish	1.0	−1.7	−2.2	3.3	0.8	−0.8	−1.3	−0.2

Source: CAPSiM simulation results.
[a] Assumes a high energy price and a high elasticity of substitution between fossil and biofuels.
[b] Assumes a low energy price and a low elasticity of substitution between fossil and biofuels.

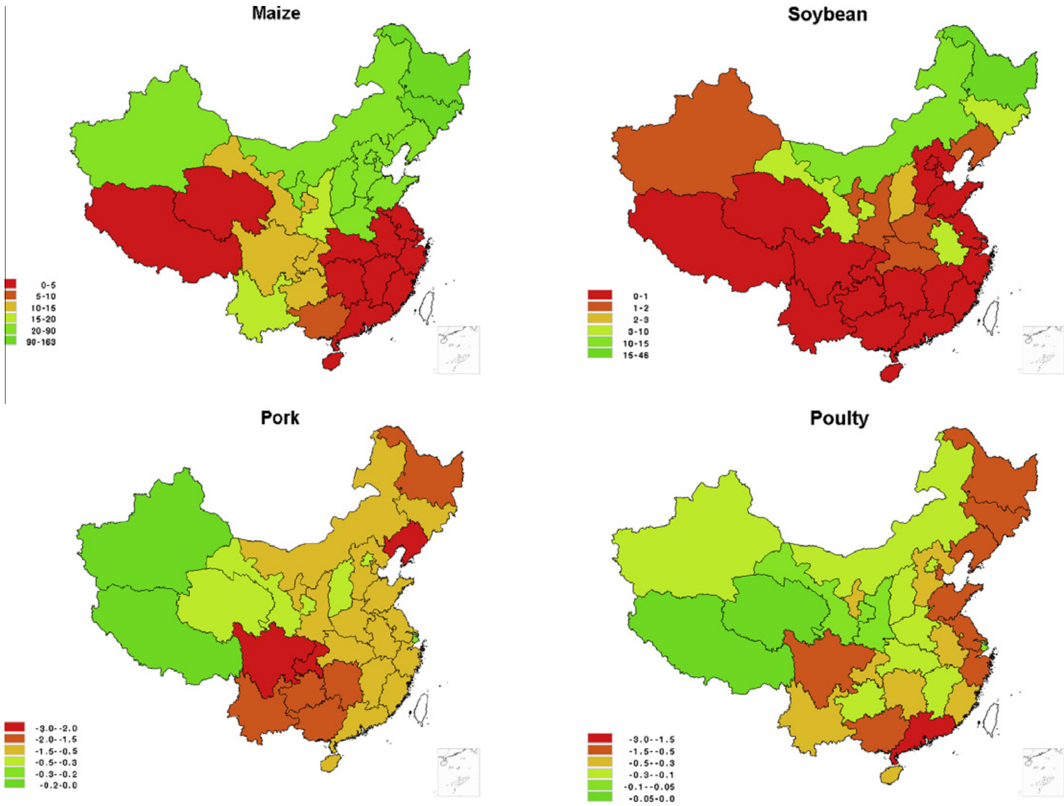

Fig. 1. Impacts on production (kg/household) of maize, soybean, pork and poultry in different provenances in 2020 under H–H scenario.

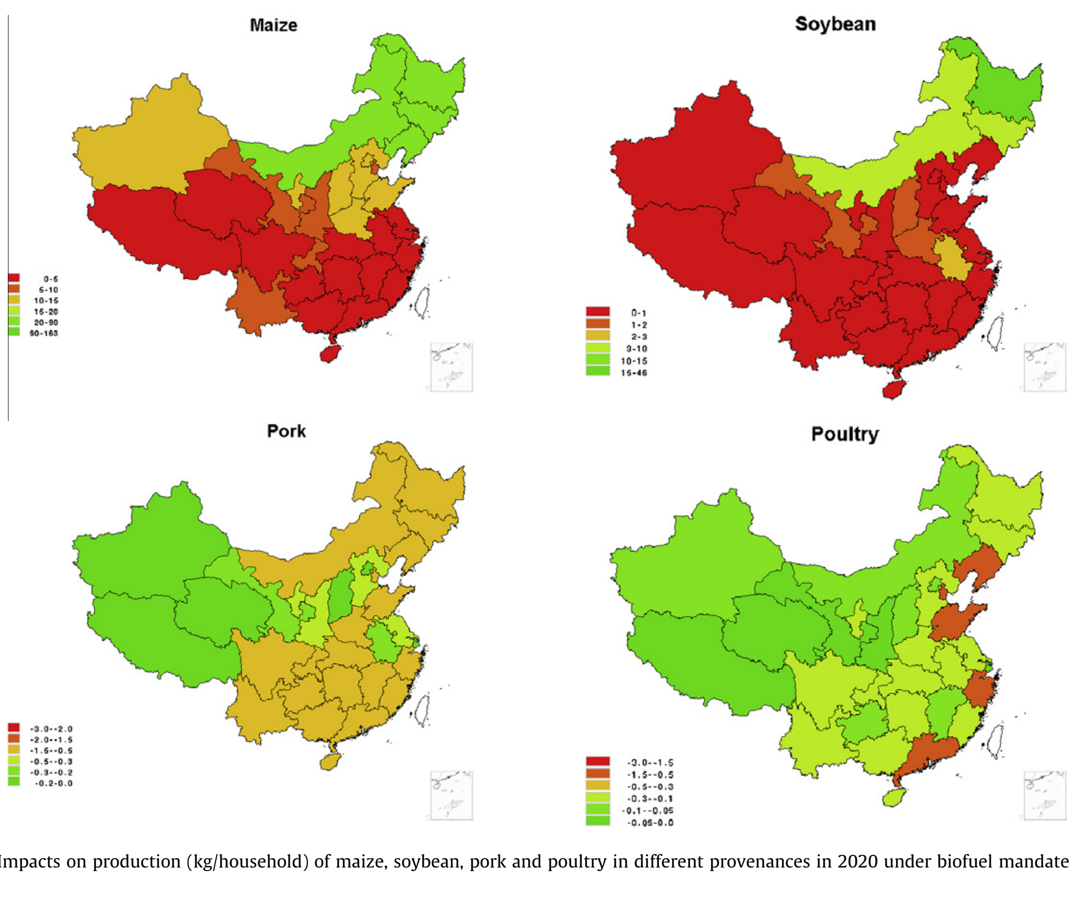

Fig. 2. Impacts on production (kg/household) of maize, soybean, pork and poultry in different provenances in 2020 under biofuel mandate scenario.

Table 5
Impacts of biofuel development on Chinese farmers' agricultural income by income groups under market and mandate scenarios in 2020 relative to reference scenario (biofuel at 2006 levels).

Income group[a]	Market[b]		Mandate[c]	
	(Yuan)	(%)	(Yuan)	(%)
National average	115.6	4.88	62.3	2.60
Income group 1 (under poverty)	47.5	6.23	25.4	3.30
Income group 2	81.8	5.28	43.8	2.80
Income group 3	106.3	5.24	56.9	2.70
Income group 4	131.6	4.91	71.2	2.60
Income group 5	163.9	4.51	89.0	2.40
Income group 6 (highest income)	157.4	4.42	85.3	2.40

Source: CAPSiM simulation results.
[a] Income groups defined as in Table 1.
[b] Assumes a high energy price and a high elasticity of substitution between fossil and biofuels.
[c] Assumes a low energy price and a low elasticity of substitution between fossil and biofuels.

relatively higher average income and lower poverty rates. Thus, the positive impacts from global biofuel growth on crop production are felt in the poorest regions of China while the negative impacts on livestock production are concentrated in the relatively wealthier regions. Meanwhile, similar results are also found under the mandate scenario, only with less impact (Fig. 2).

4.2.3. Effects on agricultural income

The nature of the production effects regionally means that the effects of the emergence of biofuels globally have relatively greater impacts on the poor (Table 5). These effects, however, do not immediately show up in absolute terms. Average producers in the higher income groups benefit the most from higher returns to crop production (higher prices and supply) and livestock production (price increase higher than production fall). For example, farmers in income group 5 (the group of farmers with income between the 70th and 90th percentile) and income group 6 (the highest decile) earn between 163.9 and 157.4 yuan more in agricultural earnings under the market scenario. These increases are cut in half if the government mandates are just met in the major biofuel producing regions. Farmers in the lowest income categories also benefit from the higher commodity prices stemming from biofuel production increases but the absolute values are approximately 25% of the increased earnings enjoyed by the highest income groups of farmers.

In relative terms, however, the emergence of biofuels globally leads to higher earnings for the poor in China compared to those in higher income categories (Table 5). With favorable market conditions for biofuels, agricultural income increases by 6.2% for those in the lowest income decile as compared to 4.4% for the highest income grouping. The absolute rates are cut in half for the mandate scenario but the relative changes are similar. Given the relative changes in agricultural returns across in income categories estimated here and the earlier descriptive finding that the poor generally earn a higher fraction of their total income from agriculture, and cropping in particular, it is almost assured that in relative terms that the poor in China from the emergence of biofuels.

The distributional impact from the emergence of biofuels globally on farmers in different regions of China is more evident at the regional level than for the country as a whole. Average increases in income are greatest for the regions with the greatest increases in production (Table 6). Thus, farmers in the northern part of the country enjoyed the largest increases in income. Average income rose by 5.5% in the Northwest, 7.0% in the North and 9.2% in the Northeast. The increases in income due to the emergence of biofuels for the other regions of the country range between 2.8% (South) to 4.0% (Southwest). Given the larger relative increases in income for poorer rural areas compared to other regions of the country, the rate of rural to urban migration may slow as a result.

Given that the average increases occur in the poorer regions of the country, the relative impacts on income distribution are also largest in these regions (Table 6). For example, the average agricultural income of the poorest decile of farmers in Northeast China increases by 20.1% with the market changes resulting from biofuel developments. Similarly, average income for the farm households below the poverty line in North China increase by 10.1%. Those areas of China (Northeast China, North China, Northwest China,

Table 6
Percentage changes in regional agricultural income by income group in China under market and mandate scenarios in 2020 relative to reference scenario (biofuel at 2006 levels).

	South[a]	East[b]	Southwest[c]	Central[d]	Northwest[e]	North[f]	Northeast[g]
Market scenario							
National Average	2.8	3.5	4.0	3.6	5.5	7.0	9.2
Income group 1 (under poverty)	3.4	3.9	5.3	6.3	6.2	10.1	20.1
Income group 2	3.0	4.3	3.5	4.2	5.6	8.0	12.0
Income group 3	3.0	3.9	4.5	3.7	5.5	8.0	7.9
Income group 4	2.9	3.3	4.2	3.4	4.9	7.2	10.3
Income group 5	2.6	2.8	3.9	3.3	5.5	6.4	9.1
Income group 6 (highest income)	2.3	3.3	3.9	3.0	5.6	5.6	8.1
Mandate scenario							
National Average	1.5	1.9	1.9	2.3	2.9	3.6	4.5
Income group 1(under poverty)	1.9	2.2	3.2	2.9	3.3	5.1	10.0
Income group 2	1.7	2.3	2.2	2.0	3.0	4.0	5.8
Income group 3	1.6	2.1	2.0	2.6	3.0	4.0	3.8
Income group 4	1.6	1.9	1.8	2.4	2.6	3.7	5.0
Income group 5	1.4	1.6	1.8	2.3	2.9	3.3	4.4
Income group 6 (highest income)	1.2	1.9	1.7	2.2	2.9	2.8	4.0

Source: CAPSiM simulation results.
[a] South (Guangdong, Guangxi and Hainan).
[b] East (Shandong, Jiangsu, Zhejiang, Fujian and Shanghai).
[c] Southwest (Sichuan, Yunnan, Guizhou, Tibet and Chongqing).
[d] Central (Hubei, Hunan, Henan and Jiangxi).
[e] Northwest (Ningxia, Xinjing, Qinghai, Shaanxi and Gansu).
[f] North (Beijing, Tianjing, Hebei, Shanxi and inner-Mongolia).
[g] Northeast (Liaoning, Jilin and Heilongjing).

Southwest China) in which farm households are producing the crops that are being used as feedstocks worldwide (maize) and close substitutes of feedstock crops (soybeans), the effects are higher than when examining the effects on households that are in areas which produce less of these crops and more livestock. Our analysis highlights the significant sectoral, spatial and distributional effects for developing country like China from global biofuel developments.

5. Summary and conclusions

In this paper, we first assess the future impacts of biofuel production on the agricultural sectors of the developed countries of the world and on world markets with and without policy mandates. According to our analysis, biofuels production levels at the mandated requirements, as set out by the domestic governments of the largest producers, will increase both prices and output for the major biofuel feedstocks. Demand from biofuel plants, in fact, is strong enough that domestic users procure enough of the output that exports fall as less of it is going onto world markets. If market conditions for biofuel production are favorable (high energy prices and easy substitution between biofuels and petroleum-based transport fuels), then the government mandates are not binding as processors of biofuels produce at levels far greater than the minimum mandated requirements. Such changes in the relative returns to biofuel production could also be stimulated through carbon taxes or other greenhouse mitigation policies. Thus, there can be significant impacts from biofuels on global agricultural markets even without direct government involvement.

We then extend our analysis beyond the borders of developed biofuel producers to the borders of China, across the borders into China's domestic economy, and down to the level of rural households. Using a set of (our own) projections of international trade dynamics and domestic agricultural market impacts inside China, we can track not only average price, production and income effects, but, we can disaggregate the effects of the emergence of biofuels globally on households by province, crop-type and income-level. This allows us to identify the impact of biofuels on the poor in different parts of China given that poverty is a rural phenomenon in China. The findings of the study are clear. In a country like China in which the poor all have access to land and in which the poor earn most of their income from agriculture (cropping), China's farmers—including the poor—benefit from biofuels.

The rising commodity prices globally under either the market or mandate scenarios are transmitted, albeit imperfectly, into China's domestic food economy. The increase in prices of all crops and livestock commodities inside China, however, is associated with different impacts on production. For those crops that are being used for feedstocks internationally (maize) or are close substitutes for feedstocks (soybeans), production rises sharply. Imports also fall significantly. Interestingly, such dynamics help China to realize its self-sufficiency goals more fully. If global biofuel production stayed at 2006 levels (our reference scenario), we predict that China's self sufficiency of grain would only be about 86.8% in 2020. Under the favorable market conditions, imports would fall by 20% and production would rise by 2.1% compared to the 2006 base, leading to rise in the self-sufficiency rate of 3.2% points to 90.0% overall.

One of the most important findings in our study is the effect on the poor. It is the poor, especially those in the northern regions of China (the Northeast, North and Northwest China) that benefit from the emergence of biofuels in terms of the share of agricultural income more than farmers in other income categories. Such a finding is in stark contrast to those that say biofuels and their global price effects uniformly hurt the poor.

Of course, we do not mean to negate the findings of others in other countries. The emergence of biofuels does translate into higher food prices for consumers, including those that produce food, but, who are still net purchasers. But, our findings show that if the poor have access to land and earn a major share of their income from agriculture, there are positive benefits. In China—a country that is certainly extreme in its situation in that virtually all of the poor have access to land—the effects are such that we are able to claim that the emergence of biofuels will nearly wipe out poverty. The importance of land policy and land tenure and the ability of the poor to benefit from pro-agricultural policies and investments are one of the main general lessons of the paper.

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