Gains from Trade: Can they be Equitable?

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Gains from Trade

1. Overview of winners and losers
    a. What do we know
    b. What are we learning?
    c. Where are we headed?
2. Ensuring gains accrue through trade negotiations
3. An Example

#1a: What do we know?

- In basic models (Ricardian), trade arises from relative productivity differences across countries. Upon free trade, GDP increases, complete specialization occurs, full employment is maintained and wages (for all) increase; consumption increases as well.
  - Can also be found in much earlier Hindu and Chinese literature
- In neoclassical models, trade is determined by relative factor endowments. Moving from autarky to free trade means GDP increases along with specialization in the good with comparative advantage, full employment occurs again, and returns to abundant factor increase (Heckscher-Ohlin). Again, consumers are on a higher indifference curve relative to autarky.

#1a: What do we know?

- In Krugman-type models, trade is driven by internal scale economies and consumer preferences for variety. Again, full employment is assumed and results in no- and free-trade regimes. "Real" wages improve with free-trade. More varieties and larger consumption of the aggregate good.
- Core assumptions in conventional thinking
  - resources move freely within and across sectors
  - countries/industries are composed of identical entities (regions/firms)
  - One-time impacts with limited attention to dynamic gains (competition and innovation)

#1b: What we are learning?

- While productivity, factor endowments, scale economies and variety preferences are all sources of trade, identification of trade's winners and losers require attention to
  - Within sector or industry effects – Melitz
    - Losers within an industry – some firms die, while others enter or expand
    - Multi-product firms – product extensive and intensive margins
  - Within country (i.e. regional) effects – new economic geography (e.g. Krugman)
    - Which regions gain or lose firms and employment?
    - Impact on regional development outcomes: wages, quality of life

#1c: Where are we headed?

- We have the ability to go from national and sectoral outcomes to regional (within-country) outcomes following trade. However, we need to broaden the scope:
  - Short-term impact evaluation; missing are counterfactuals such as "what if no trade had occurred between U.S. and China (or India)?" and long-term assessment of consequences
  - full-employment models, hampering our ability to inform the critical question on trade and wages/employment (Head and Larch, JIE 2016)
  - Sectors and aggregates with little attention to supply chains, off-shoring and break-up of production processes, and investment
- Hopeful that emerging advances in data, methods and computational capabilities can fill the gaps.

#2: Ensuring Gains Accrue and Losses are Mitigated?

- By focusing on gains from trade within a country (regions) and industry, we stand a better chance of trade reform:
  - You need votes in U.S. Congress or European or Indian parliament constituted by regional representatives.
  - Focus on resources specific to regions/industries and their cost of adjustment
    - safety nets that account for such adjustment costs
- Improve communication of trade outcomes
  - Role of technological change, skill upgrading
- Static policies reduce uncertainty, but need a balance between anticipated outcomes and lowering risk

#2 Bilateral vs. multilateral agreements

- As we focus on within-country and –industry effects, opportunities may arise in the bilateral or multilateral context for trade reform:
  - A rich literature has explored the merits of bilateral vs. multilateral agreements and whether or not global reform can be achieved one pair at a time.
  - Bilateral agreements are more attractive
    - Can include TRIPs, TRIMs, offshoring and services
  - but, they cannot be beneficial without multilateral (WTO) disciplines, especially non-discrimination (aka MFN status) and reciprocity: Baldwin (2016)
  - Bilaterals require lot more human capital

#3 An Example

- It is the job of researchers and policy analysts to investigate and effectively communicate gains from trade (globalization in general) for use in negotiations, drafting policies/agreements and evaluating impact.
  - Hope to demonstrate it with the following example
- Market Impacts of China and India Meeting Biofuel Targets Using Traditional Feedstocks
  - By Beckman, Gooch, Gopinath and Landes
  - *Biomass and BioEnergy*, 2018, Volume 108, pp.258-264.

Context: Energy and GHG Emissions

- A major source of emissions is transportation: fossil fuels
- Alternative to fossil fuels: solar, wind, wave, geothermal
- Many require substantial upfront or fixed costs
- Short-term options include blending biofuel to fossil fuels
- Paris agreement: self-chosen targets include both short- and medium-term options

Context: China and India

- Large, fast-growing transport fleets and fuel demand
- Land and water resources are limited for massive expansion of feedstock production for biofuels
- Current regulations
  - little to no competition between food and biofuel feedstock production (China - no arable land for feedstock production; India - domestic production from molasses only)
  - Trade policies (tariffs, use limitations)

Recent Data on Biofuels: China and India

	Biofuel	Actual blend rate (2015)	Target blend rate	2011 biofuel production (dam3)	2015 biofuel production (dam3)	Target biofuel consumption (dam3)	Additional biofuel to meet target (dam3)	Tariff, value added tax, consumption tax
China	Ethanol	2.60%	10%	2567	3078	19,329	15,541	40%, 17%, 5%
	Biodiesel	0.10%	2%	220	511	3350	1580	6.5%, 17%, 5%
India	Ethanol	2.30%	10%	360	669	5039	2995	26.42%
	Biodiesel	0.08%	20%	30	121	16,826	16,641	26.42%

A CGE Model

- GTAP-Energy model with 2011 baseline
- Calibrated to 2020
- Consider four scenarios to achieve blending targets
  - Status quo
  - Eliminate domestic regulations
  - Alternative feedstocks (short-term again!)
  - Trade policy change

Results

- Scenario 1: status quo but meet blending targets
  - Production needs to increase dramatically (grains 20% in China; vegetable oil by 156% in India)
  - Significant price increases for food commodities
  - Trade volumes increase due to displacement
- Scenario 2: remove domestic regulations
  - Similar to scenario 1 (ethanol has the largest impact on China and biodiesel on India)
  - Sugarcane production is largely irrigated. Without additional water resource, relaxing the restriction on sugar juice uses doesn't significantly alter the outcomes

Results (contd.)

- Scenario 3: alternative feedstocks
  - We are years away from 2nd and 3rd generation feedstock technology
  - Wasted cooking oil for biodiesel? (Moldy) Stockpiles of maize in China?
  - China made substantial progress, but prohibitive costs and sale limitations have slowed down this prospect
    - Good use of rotting grain stocks!
  - India
    - Lowers vegetable oil production increases to 80 percent
    - Major challenges in implementing this strategy!
    - Positive health externalities

Scenario 4

- Scenarios 1-3 rely on domestic resources, which are severely constrained (more land, water and labor in rural areas?)
  - Continue to stress physical and economic environments (negative externalities)
- How about a trade scenario?
  - What if we lowered import tariffs and regulations?
  - Turns out, as expected, we don't have to produce as much feedstocks as required in scenarios 1-3. Also, prices of food commodities don't go up as much as in scenarios 1-3.

Win-Win Strategies?

- Foreign investment and trade in biofuels as well as tapping wasted cooking oil
  - Lower emissions (mitigate cancer/type II diabetes incidence) and improve quality of life
  - Biofuels are blended at point of use (cities)
    - Foreign investment in blending infrastructure can create jobs
    - Domestic industry adversely affected? Some upstream or downstream segments?

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Research paper

Market impacts of China and India meeting biofuel targets using traditional feedstocks☆

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ABSTRACT

Biofuel production has largely occurred in Brazil, the European Union (EU), and the United States (U.S.), but several other countries have articulated large biofuel targets. Among them, China and India stand out with large populations, with a prominent food versus fuel debate. Recent research has recognized the importance of biofuels in replacing traditional transportation fuels in these two countries; but such work has largely considered unconventional pathways such as lignocellulosic feedstocks. This work takes a more straight-forward approach, using a computable general equilibrium (CGE) model to estimate the market impacts of achieving biofuel targets in 2020. Along with projections in food and fuel demand to 2020, we also consider several options in meeting biofuel targets. China's biofuel policy focuses on ethanol, and the result of meeting a 10 percent ethanol blend target, along with food and feed demand, is an increase in coarse grain production of 19 percent. India's largest potential biofuel component is biodiesel, where reaching a 20 percent target would entail a triple-digit increase in vegetable oil production. Results indicate that these impacts could be somewhat mediated if biofuel trade access is increased; in addition, utilizing stockpiled grain in China, or implementation of an effective waste cooking oil collection-to-biodiesel program in either country could substantially reduce agricultural feedstock requirements.

1. Introduction

Biofuels produced from lignocellulosic feedstocks, i.e., non-food/feed sources, remains the ultimate goal of providing green energy; however, the economic feasibility of large-scale production of such feedstocks remains a significant challenge. In the near future, biofuels produced from feedstocks that compete with other food and feed uses remains the only viable option. Countries have signaled in their intended national determined contributions (INDC) that biofuels are an option to reduce greenhouse gas (GHG) emissions from transportation. However, a collision between the fuel and food/feed demand satisfaction is highly likely for some of the countries of the Paris Agreement.

China and India are two key ‘food versus fuel’ examples, where ambitious biofuel targets collide with the need to feed over a billion people each. In addition, both countries have rapidly expanding fuel fleets, with projections for transport fuels doubling for India by 2026 [1]. However, biofuel production growth has been slow, both countries have actual biofuel blend rates of less than 2 percent. One reason for the slow growth in biofuel production is that they both have rules to limit competition with food uses. For example, China has removed policy support for grain-based ethanol, mandating that biofuel feedstocks not compete with feedstocks intended for human or animal consumption [2]. India restricts feedstock use for biofuels, such as prohibiting the use of sugar-cane juice for ethanol production. The pledges made by China and India in the Paris Agreement could, however, push them to focus more on biofuel strategies. China [3] notes that they will proactively develop bioenergy. India's INDC [4] notes the national policy on biofuels is a 20 percent blending rate for both biodiesel and ethanol.

Some studies have explored unconventional ways (i.e., lignocellulosic ethanol or feedstocks grown on marginal land) for these countries to meet their targets. Wang and Shi [5] investigate the optimal utilization of marginal land for biofuels in a province in China; Qui et al. [6] provides information on the feasibility and geographical location of lignocellulosic feedstocks in China. For India, Sasmal et al. [7] considered the potential of non-conventional biomass in North-East India; Lavanya et al. [8] conducted a study to identify high yielding castor that could be used for biodiesel. The scope of these newer opportunities to help meet biofuel target of these two countries remains limited, similar to the situation in Brazil, EU and U.S. Moreover, few studies have examined how meeting 2020 targets with unconventional

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and/or traditional feedstocks will impact domestic and global food and feed markets. In addition to the desire to lower GHG emissions, the rules limiting competition between food and fuel uses, and limited infrastructure for lignocellulosic feedstocks raise serious doubts on these countries ability to achieve targets pledged under the Paris agreement.

In this study, we use a computable general equilibrium (CGE) model to analyze each country meeting their biofuel targets, focusing on commodity price impacts for domestic and global consumers, as well as shifts in global trade patterns. An examination of each countries' biofuel production, feedstocks used, and trade provides information on additional options to meet their targets. These are grouped into four categories: reconsidering restrictions on ethanol feedstocks, an expansion of ethanol feedstocks, an expansion of biodiesel feedstocks, and a reduction in trade barriers. The market impacts of each scenario are very large and the size of the adjustments to supply, demand, and prices is well outside the range of the historical data; thus, the focus here is on changes in magnitude across scenarios to help evaluate the feasibility of the adjustments that may be needed to meet the policy targets.

2. Background

With tremendous growth in production, biofuels have become a major source of energy in several countries. Major producers include Brazil, the EU, and U.S., however, each of these regions have reduced their mandates at some point in the last five years [9]. As such, other countries might be good candidates to provide future growth. Because of the amount of transportation fuels they consume, the biofuel targets set out by China and India are two of the more interesting cases. In addition, having the largest and second-largest populations makes the food versus fuel argument a relevant theme in their energy policy.

2.1. China

China is currently the third largest producer of ethanol in the world; in addition, biofuels are a part of China's long run energy plan. However, policies encouraging or mandating the production of biofuels frequently change. In early 2000, China implemented an ethanol program in response to abundant grain supplies [2]. However, the rapid increase in commodity prices (and commodity price volatility) in 2007 and 2011 triggered several changes to the biofuel program. For example, policy now dictates that biofuel production should not use crops intended for human or animal consumption. As part of their 12th Five Year plan (FYP), which ended in 2015, China set a target of producing 4.5 hm3 of ethanol and 1.1 hm3 of biodiesel; however, only the biodiesel target was reached. China's 13th FYP (2016–2021) increases those targets. By 2020, China targets the production of 6.3 hm3 of ethanol and 2.3 hm3 of biodiesel annually. These targets imply a 100 percent expansion of its production capacity of ethanol over the five years and even larger development of biodiesel production [2].

2.1.1. Ethanol

Although China has not met its ethanol production target, production has increased from 1.7 hm3 in 2006 to 3.7 hm3 in 2015 (Fig. 1). There are three avenues through which this expansion took place: (1) more refineries, (2) of these refineries, a number of the new ones were 1.5 generation (non-grain based feedstocks) and 2nd generation (lignocellulosic) technologies which received subsidies, and (3) each refinery increased their operating capacity. The driver of this increased production was increased demand [2]. Ethanol blend targets have increased in 2016, though a national mandate has yet to be implemented. As of 2016, a total of 10 provinces and a number of municipalities use E10 blending zones which is up from 6 provinces since 2015. During late 2015 to the middle of 2016, the largest fuel consumption regions were Guangdong, Jiangsu, and Hainan provinces and Beijing and Tianjin cities [2].

Although China has tried to move away from using feedstocks that could compete for food uses, corn and wheat remain the largest input sources for ethanol (Table 1). Combined, the two feedstocks accounted for 80 percent of ethanol inputs in 2015. The supply of Chinese corn, however, is exposed to a number of regulations and current events. Corn destined for fuel production cannot be grown on arable land; therefore, the corn used in ethanol production has been limited to the harvest from marginal lands within China. In 2014, China began to import ethanol for the first time. Imports were cheaper than domestically produced ethanol in 2015 (470 \$ m^3 versus 620 \$ per m^3). Imported ethanol is primarily used for fuel and is monitored by the government. With the pending increase in domestic demand for ethanol, increased imports may become inevitable [10]. For the work here, we only consider China's use of current, 1st generation feedstocks.

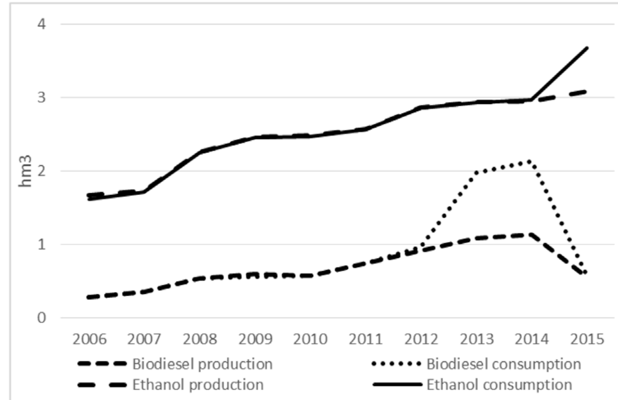

Fig. 1. China biofuel production and consumption.
Source: [2].

2.1.2. Biodiesel

Between 2010 and 2014, Chinese biodiesel production grew around 16 percent spurred by fiscal incentives and the crackdown of the illegal use of waste cooking oil for human consumption. Production reached around 1.1 hm3 in 2014 before it collapsed by more than 50 percent in 2015 (Fig. 1) due to consumer complaints over fuel quality and a decision by oil companies to curtail purchase of used cooking oil [2].

By 2015, nearly all biodiesel was made from waste cooking oil. However, in 2015, the two major Chinese oil companies, Sinopec and CNOOC, stopped buying biodiesel for two reasons: (1) the biodiesel is of poor quality and (2) it has a high cost. Because of the withdrawal of the main consumers of biodiesel, producers of biodiesel have also withdrawn from the marketplace [11]. Capacity is estimated to be at 3.8 hm3; however, the utilization rate is 27 percent due to the lack of large scale collection channels for waste cooking oil. By the end of 2015, there are only 31 biodiesel plants leftover from the peak of 84 in 2008, but more than one third of these 31 producers have either ceased production or operate well under capacity. Part of the difficulty in expanding biodiesel production in China is that state owned oil companies block biodiesel from being sold to most consumers. As a result most biodiesel is sold at private gas stations in small cities or in the country side [2]. Since 2012, China has imported biodiesel to help meet domestic consumption, almost all these imports have been from Indonesia. These imports were substantial in 2013 and 2014 (note the difference in production and consumption in Fig. 1); however, 2015 imports were small. Biodiesel is only approved for fuel use in select cities [2].

2.2. India

The Government of India (GOI) proposes to reduce its dependence on crude oil imports by ten percentage points in several ways: increasing domestic output; promoting energy efficiency and

Table 1
Annual feedstocks for China and India biofuel production.
Source: [1] and [2].

Feedstocks (1000 Gg)		2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
China	*Ethanol*										
	Corn	3233	3385	3608	3614	3641	3645	3563	3389	3381	3570
	Wheat	1050	1050	1050	1050	1050	1050	1050	1050	1050	1050
	Sorghum	0	0	0	0	0	0	0	0	90	360
	Cassava	0	0	364	467	392	336	336	392	504	504
	Corn cobs	0	0	0	0	0	0	0	240	250	260
	Biodiesel										
	WCO	267	344	522	578	556	722	889	1055	1108	512
India	*Ethanol*										
	Molasses				417	208	1521	1271	1592	1458	2854
	Biodiesel										
	WCO				35	38	42	48	50	55	60
	Animal fats				3	6	6	7	7	6	5
	Other oils				30	50	58	60	65	65	70

Note: WCO is waste cooking oil.

conservation; and encouraging greater use of alternative fuels [4]. However, most of their efforts to increase biofuel production have not panned out. Ethanol consumption has increased, but biodiesel consumption has rested on the hopes of using industrial vegetable oils.

2.2.1. Ethanol

India's ethanol program currently "mandates" a 5 percent blend rate for gasoline, with the Government considering an increase to 10 percent. Actual blending has never reached the targeted rate because of inadequate domestic supplies, inadequate price incentives for ethanol producers and blenders, and a requirement that fuel ethanol, as opposed to ethanol destined for industrial or chemical use, be supplied from domestic sources. In 2015, India produced 2.1 hm3 of ethanol, with 609 dam3 used for fuel (the rest was used for industrial purposes), for a blending rate of about 2 percent of total gasoline consumption. This was an increase from an average of 344 dam3 during 2012-14 (Fig. 2), resulting in increased demand for ethanol imports for nonfuel uses. Ethanol imports, which are subject to a 2.5 percent tariff, reached 450 dam3 in 2015 [1]. India exports relatively small amounts of ethanol.

India's ethanol is produced almost exclusively from molasses that is a co-product of domestically produced cane sugar, of which India is the second largest global producer (after Brazil) and a variable net trader. Production of molasses and ethanol are linked closely to production of sugarcane, which is cyclical. Cycles are created primarily by price support policies for sugarcane that require sugar mills to pay growers based on costs of production rather than price conditions in the sugar and byproduct markets [13]. Although most (94 percent) sugarcane is irrigated [14], abnormally dry weather that limits irrigation water supplies can also be a source of variation in yields and production in some areas.

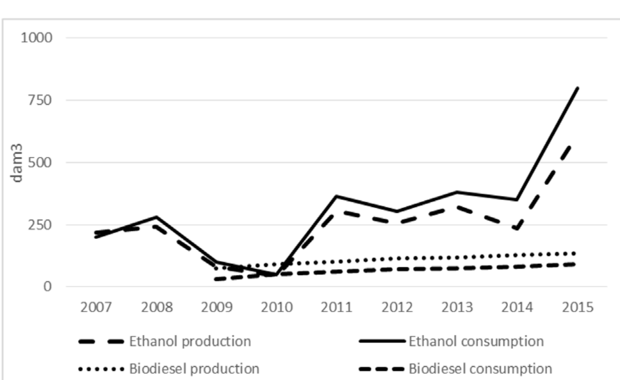

Fig. 2. India biofuel production and consumption.
Source: [1].

A key implication of India's current requirement that ethanol be produced from molasses rather than directly from sugarcane juice is that expansion of ethanol production can only occur to the extent that the associated sugar production can be efficiently disposed of in domestic and global markets. Meeting either a 5- or 10-percent ethanol blend target from molasses would appear to entail unrealistic gains in Indian sugar consumption and exports, and declines in sugar prices.

2.2.2. Biodiesel

Biodiesel is a significantly more nascent industry in India than ethanol but, because of the much greater role of diesel as a motor fuel in India, may have greater potential to mitigate GHG emissions. India is the world's third largest consumer of edible oils (after China and the EU), but these edible oils are not used to produce biodiesel [1]. Efforts to expand production of industrial vegetable oils, such as jatropha, for use in biodiesel have met with very little success over 20-plus years of field trials. Only 136 dam3 of biodiesel were produced in 2015, for a blending rate less than a tenth of a percent. There are 6 refineries capable of producing around 473 dam3 of biodiesel; however, capacity utilization has never been above 30 percent [1]. In addition, the cost of biodiesel production is found to be 20 to 50 percent more expensive than the set purchase price established by the government [15].

Biodiesel prices are market-determined and, with the decontrol of diesel fuel prices implemented in October 2014, diesel prices are now also set in the market. Assuming that decontrol remains in effect if world oil prices return to higher levels, this measure may create more incentive to produce and use biodiesel when market prices rise [1]. Prior to decontrol, incentives for biodiesel production were limited because biodiesel costs were typically higher than those for diesel fuel. Biodiesel imports are currently made economically unviable by a 26.42 percent tariff.

3. CGE model

Given the complex links and interactions between agricultural commodities, competition among these commodities for limited economic resources, as well as interactions between the production, consumption, and trade activities, an economy-wide CGE modeling approach provides an appropriate framework to analyze the impacts of biofuel policies. For this work we begin with the model built in Ref. [16], adding to it the necessary components to model the alternative biofuel scenarios (as noted in each section below). In addition, we use

Table 2
Updating and reference scenario shocks (fractional changes).
Source: [18].

	GDP		TFP		Capital		Labor		Investment		Population	
	2011–2015	2015–2020	2011–2015	2015–2020	2011–2015	2015–2020	2011–2015	2015–2020	2011–2015	2015–2020	2011–2015	2015–2020
Brazil	−32.12	15.03	2.37	6.56	14.13	18.66	3.91	5.55	−3.67	13.74	3.66	5.96
Canada	−13.32	13.11	4.61	8.15	13.09	13.94	0.58	1.97	11.32	13.12	4.39	4.54
China	45.03	38.47	20.98	27.33	45.77	45.01	2.91	−0.67	27.90	44.05	2.02	5.75
EU	−11.43	9.16	7.25	9.53	6.11	10.21	−0.43	−1.38	8.52	16.66	0.82	4.51
India	12.95	30.05	9.45	16.99	27.06	28.42	8.63	8.34	0.77	26.72	5.10	5.36
Mexico	−2.14	19.05	4.82	7.31	13.77	20.44	6.65	8.31	14.49	20.60	5.53	−3.31
U.S.	15.65	9.59	4.06	4.71	9.25	12.51	2.89	2.30	34.89	6.61	3.11	1.50
ROW	−4.73	15.97	3.09	8.67	12.43	17.07	7.18	8.64	17.52	18.42	3.53	5.36

the most recent Global Trade Analysis Project (GTAP) database (set to 2011), splitting biofuels into three types: grain-based ethanol, sugar-based ethanol, and biodiesel. Note that India's ethanol production will be from all sugar, based on these modeling assumptions. See the supplementary material for more explanation of the model.

Because biofuel production in China and India has increased since 2011, we conduct an updating procedure to bring the model to 2015. Another important change since 2011 is the decrease in global oil prices, which alters the incentives for biofuel production. In addition, we update agricultural commodity prices used for biofuel feedstocks. The updating procedure follows the approach by Ref. [17], who show that by shocking population, labor supply, capital, investment and productivity changes, along with the relevant energy price and biofuel policy shocks, the resulting equilibrium offers a reasonable approximation to key features of the more recent economy. Actual, historical changes are provided by the literature for population, GDP, and commodity prices changes. Updates to labor supply, capital, investment, and productivity are calculated based on [18]. See Table 2 for the exogenous shocks used to update the model.

3.1. Scenarios

With the updated database and model in hand, we conduct several biofuel policy experiments based on the situations in China and India. The first step is to project the model forward to 2020, the year by which we assume the targets will be met. Again, we use projections for the exogenous shocks (shown in Table 2 as 2015–2020). In addition, we use projections of gasoline and diesel use to determine how much biofuel will be needed in 2020 (Fig. 3). This is important because both countries have expectations of increased traditional transportation fuel usage. India's expanding inventory of about 210 million registered motor vehicles now consumes about 125 hm3 of fuel annually and demand is projected to rise 6 percent annually, making India a large potential biofuel consumer [4]. The majority of India's fuel

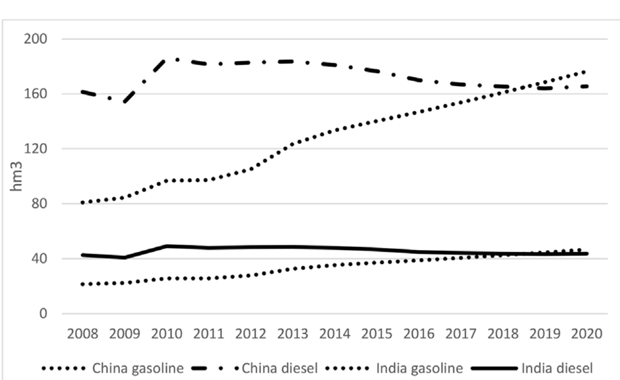

Fig. 3. Fuel projections.
Source: [1] and [2].

consumption is with diesel. Chinese diesel consumption is actually expected to continue its recent decline; gasoline consumption is projected to be the larger of the two by 2020. The amount of biofuels necessary to meet the targets are given in Table 3. Note that China's five-year plan amounts (see 2.1) would only lead to a 3.3 percent national blend rate in 2020. For purposes of this analysis, we consider the 10 percent national blend rate. Note that we could have just ran one scenario (2011–2020), but the model would have been more difficult to solve then breaking it into two components (2011–2015; 2015–2020) as 2011–2020 were very big changes in biofuels production.

The scenarios we consider regarding meeting biofuel targets include (on top of the demand changes from the exogenous shocks used to update the model):

1) Restrictions to ethanol feedstocks. This scenario specifies that China pursues the status quo in producing ethanol (i.e., no stockholdings are used). For India, this involves restricting growth in sugarcane production (i.e., no land can move into sugarcane production) as an important constraint to the expansion of sugarcane-based ethanol production includes the relatively high water intensity of Indian cane production. Although average sugarcane area accounts for only about 3.6 percent of net cropped area and 7.3 percent of irrigated area, it is among the most water-intensive of Indian crops and its contribution to the deterioration of groundwater supplies is a potentially significant externality in the areas where it is grown.
2) An expansion in ethanol feedstocks. For China, this involves providing an increase in available feedstocks made feasible by large grain stocks. India has the land-constraint on sugarcane production lifted for this scenario. More information on China's stockholding is given in the next section.
3) Introduce the possibility of using waste cooking oil for biodiesel production. We provide details on the possible amounts of WCO for each country later.
4) A trade scenario that removes tariffs on biofuels imports into each country. In 2015, China's ethanol imports accounted for almost 20 percent of its consumption. The amount for India is smaller. To make large-scale imports of ethanol more feasible in the model, we assume that all India's ethanol imports can be used for fuel and not limited to non-fuel uses under current policy.

3.1.1. An expansion in ethanol feedstocks

The scenario to expand ethanol feedstocks focus on ways to alleviate the pressure on ethanol feedstock production and prices. For China, much attention has been made about grain reserves [1], estimates that these reserves are at 226 Mt. Of those reserves, China currently holds an estimated 104 Mt of corn in government stockpiles, of which 20 Mt is so moldy that ethanol production is the only realistic use [19]. In 2015, China used 3.6 Mt of corn in ethanol, 20 Mt of moldy reserves is much more than current use. To simulate this increase, we calibrate a change in productivity of current ethanol feedstocks to the moldy amount (see the supplementary material for more explanation). For India, the

Table 3
Model scenarios.
Source: [1] and [2].

	Biofuel	Actual blend rate (2015)	Target blend rate	2011 biofuel production (dam3)	2015 biofuel production (dam3)	Target biofuel consumption (dam3)	Additional biofuel to meet target (dam3)	Tariff, value added tax, consumption tax
China	Ethanol	2.60%	10%	2567	3078	19,329	15,541	40%, 17%, 5%
	Biodiesel	0.10%	2%	220	511	3350	1580	6.5%, 17%, 5%
India	Ethanol	2.30%	10%	360	669	5039	2995	26.42%
	Biodiesel	0.08%	20%	30	121	16,826	16,641	26.42%

restriction on the amount of land allocated for sugarcane production is lifted in this scenario.

3.1.2. Biodiesel feedstocks

For biodiesel, waste cooking oil is an oil-based substance consisting of edible vegetable matter that has been used in the preparation of foods and is no longer suitable for human consumption. WCO has been used as an ingredient in animal feed in some countries as well as an input into soap and other industries [20]. As noted by Zhang et al. [21], converting WCO into biodiesel represents a three-win solution, dealing simultaneously with food security, environmental issues, and energy security. As pointed out in Kalam et al. [22], disposing of WCO into drains or sewers leads to blockages, and if dumped in municipal solid waste landfills or into municipal sewage treatment plants it creates operation problems along with pollution of water and soil.

The scope for waste cooking oil is not known with certainty, but if significant amounts of waste cooking oil can be recycled as biodiesel, substitute for some share of petroleum imports, and also reduce GHG emissions, WCO could be a win-win-win outcome. While much of the edible oil used by households and small-scale enterprises may not be accessible for recycling, that used by restaurants and commercial processors might be available for recycling as biodiesel. We simulate the use of waste cooking oil for biodiesel production based on our calculations for available feedstocks. See the supporting material for more information on how we arrive at the estimates of waste cooking oil availability.

4. Results

As discussed previously, we project the database forward to 2020 by providing updates to demand and supply forces. Results are presented for China, India, and the Rest of the World; detailed results for other agricultural commodities or regions (Brazil, Canada, the EU, Mexico, and the U.S. are disaggregated in the database) are available upon request. Emission reductions from replacing traditional transportation fuels with biofuels will be the same across all scenarios (since each country is meeting a consumption target), thus the focus of the results is on changes to production, prices, and trade of biofuels and their main feedstocks.

4.1. Restrictions to ethanol feedstocks

This scenario fulfills the biofuel targets assuming the status quo in China, while restricting the amount of land that can be used for sugarcane production in India. For China, the imposition of the 10 percent ethanol target leads to an increase in ethanol production (Table 4), as production increases from 3.1 hm3 to 17.4 hm3. China imports a portion of ethanol consumption (1.8 hm3), but ultimately the largest increase is in domestic production. This increase in ethanol production leads to an increase in the domestic price of ethanol of 31 percent. Although China was the 3rd largest producer of ethanol in 2015, their production was only about 3 percent of global production. Assuming global production stays the same, China's share would be much larger (16 percent) in 2020; thus their increase in ethanol price transmits to global prices (19 percent). To produce more ethanol requires additional feedstocks, coarse grain production increases by 19 percent. Table 4 indicates that the demand changes from the exogenous shocks leads to an increase in coarse grains production of almost 12 percent. Thus when combined with biofuel targets, the population and income changes are responsible for the largest share of feedstock changes (63 percent). The price of coarse grains increases in the ROW, but this change is less than that for China. Much of the increase in the ROW coarse grain price is embedded in the demand shocks. That is, the price increases by 48 percent with exogenous shocks and 57 percent when biofuel targets are added. Biodiesel production in China increases as well to meet their target; in addition, their production of the feedstock (vegetable oil) also increases. The 15 percent increase is greater than the increase from the demand shocks (9 percent), even though the biodiesel target is only 2 percent.

For India, ethanol production increases by 1235 percent to meet their 10 percent target. Restricting the amount of land for sugarcane leads to a small increase in sugarcane production, as there is still an increase due to the agricultural productivity shocks from the 2020 projection. Because ethanol production must occur, the amount of sugarcane allocated to the ethanol sector increases and the amount of sugarcane used for most other activities decreases. The largest users of sugar in India are the processed food industries and beverages and tobacco, these sectors have a positive increase in use (due to the demand projections) but all other sectors have a decrease. In addition, there is a large decrease in exports of processed sugar in India of 67 percent in this scenario. For reference, there was a reduction in sugar exports due to the demand projections of 21 percent. The biodiesel target is even larger than that for ethanol (and base biodiesel production is smaller), biodiesel production in India increases by almost 15,000 percent. This dictates that a lot of resources must be reallocated to the vegetable oil sector, production increases by 156 percent. This pushes up vegetable oil prices in India. With the exogenous shocks only, prices increase by 32 percent, with the mandate they increase by 165 percent. This, and the increase in food demand from the exogenous shocks, leads to increases in food prices in India that are much larger than those for any other country. China and India are the two largest importers of vegetable oils, but there is a reduction in vegetable oil imports for China compared to the exogenous shocks as all vegetable oils used for biodiesel production are domestically sourced. On the other hand, India has a large increase in imports from meeting the biodiesel target.

4.2. Increasing ethanol feedstocks

The work from the supplementary material indicates that moldy feedstocks could supplant 13 percent of the coarse grains need to produce ethanol in China. The ethanol restriction scenario led to an increase in coarse grains production of 19 percent, or an increase of 7 percent compared to the demand projections. Now, coarse grains production increases 18 percent. This increase in feedstock availability puts less pressure on prices and also results in less imports of coarse grains into China. If we had used the entire stock of corn reserves to produce ethanol, the amount of feedstocks necessary would have been even less. However, whether it is only the moldy reserves or the entire

Table 4
Model results (fractional changes).

Scenario	Commodity	Production			Prices			Trade		
		China	India	ROW	China	India	ROW	China*	India*	ROW′
Exogenous shocks	Ethanol feedstockˆ	12	8	4	77	73	48	37	39	12
	Vegetable oil	9	2	12	43	32	29	71	26	22
	Ethanol†	53	59	18	17	7	6	111	91	122
	Biodiesel	21	25	8	32	24	23	45	17	12
Restrict ethanol feedstocks	Ethanol feedstock	19	7	3	101	135	57	45	154	13
	Vegetable oil	15	156	19	53	165	40	67	182	39
	Ethanol	471	1236	16	31	19	19	110	61	100
	Biodiesel	657	14,622	2	40	132	23	122	37	2
Increase ethanol feedstocks	Ethanol feedstock	18	7	3	98	136	57	43	156	13
	Vegetable oil	15	155	19	52	163	40	67	181	39
	Ethanol	472	1236	15	20	19	8	110	60	100
	Biodiesel	657	14,633	2	40	130	23	122	40	3
Biodiesel feedstocks	Ethanol feedstock	18	10	4	95	100	52	45	85	13
	Vegetable oil	11	81	15	47	76	34	68	91	30
	Ethanol	461	1231	16	29	12	17	102	47	103
	Biodiesel	659	14,712	5	36	60	21	164	87	7
Trade	Ethanol feedstock	17	5	4	95	124	59	40	126	13
	Vegetable oil	15	149	19	52	153	40	67	172	38
	Ethanol	342	706	17	28	17	24	826	487	278
	Biodiesel	651	13,974	4	40	123	24	1108	1770	17

Notes: ˆ the ethanol feedstock for China is coarse grains, sugar for India, coarse grains for ROW, † is grain based ethanol for China, sugar based ethanol for India, and all ethanol for ROW, * is imports, and ‘is exports.

reserves, both are only a one time occurrence for production. China's biodiesel sector experiences much of the same changes as those in the previous scenario; although there is a slight decrease in vegetable oil price (52–53 percent) due to less competition for agricultural land.

For India, ethanol production increases by the same amount as in the previous scenario; there is also little change in sugar production and prices. This is because when we remove the land restrictions, the amount of land used for sugar production only increases by 0.17 percent. Thus, the land-restriction specification has little impact on India due to the restrictive nature of India's sugar production (i.e., the water-intensive nature). The biodiesel aspect of this scenario does not change, thus the results for biodiesel and vegetable oil are the same as in the previous scenario.

4.3. Biodiesel feedstocks scenario

This scenario considers the expanded use of waste cooking oil for biodiesel, the shock is administered by creating a WCO by-product (of vegetable oil production) and allocating WCO to bidiesel. For China, the boost in productivity reduces the increase in vegetable oil production relative to all other biofuel scenarios. China imports raw oilseeds in large amounts (unlike India, which imports mainly vegetable oil); in the other biofuels scenario imports of soybeans from the United States increased by 27 percent; when vegetable oil productivity in biodiesel is implemented, the increase is reduced to 24 percent. The smaller changes in vegetable oil production and smaller biodiesel mandate in China could lead to China exporting biodiesel to India; however, there was no trade in the base year of the CGE model, thus subsequent no trade occurs.

The large biodiesel target (and small base production) led to changes in India biodiesel production of at least 14,000 percent in the previous biofuel scenarios; this large percent increase led to a large increase in the production of vegetable oils, especially compared to the increase from the demand projections alone. The use of WCO for biodiesel substantially mediates this change. In previous scenarios, production of vegetable oil increased by 150 percent, when WCO is used for biodiesel increases, the increase in production is 81 percent. This translates to a smaller increase in the price of vegetable oil; thus, using waste cooking oil would benefit food consumers in India. In addition, using waste cooking oil essentially reduces the amount of diesel needed for transportation; however, this win-win for consumers and the environment faces large obstacles for large-scale production in India.

4.4. Trade scenario

The last scenario considers changes in trade flows of biofuels to China and India. For China, ethanol imports increase by 826 percent, compared to the 110–114 percent increase in the previous scenarios. More imports would mean that China's biofuel import bill increases; however, recall that China could import ethanol at a cheaper price than it could produce (Section 2.1.1). More imports means that China needs less domestically produced ethanol; in addition, there is a smaller increase in the production of coarse grains compared to all other scenarios except for ethanol feedstock expansion. Forcing China to meet their ethanol target dictates that resources must be pulled from other crops (and perhaps other land-uses); using imports to meet a larger share of the target should lead to more allocative efficiency in crop production. The price increase for ethanol and coarse grains is also somewhat mediated compared to other scenarios, the ethanol price increase in the ROW is the largest, due to the increase demand for trade in China. Unlike ethanol, biodiesel base imports are very small; although the fractional change in biodiesel imports from this scenario is large, the reduction in domestically produced biodiesel in China is small (651 percent compared to 657 percent). This slight difference does not impact the amount of vegetable oil produced in China, nor does it impact the price of vegetable oil in the country.

The trade scenario also leads to an increase in imports of biofuels in India. Ethanol imports increase considerably compared to other scenarios, this puts less pressure on domestically produced ethanol. Less domestically produced ethanol leads to the smallest increase in sugar production across all scenarios; in addition, India imports less sugar. The increase in ethanol imports does increase India's ethanol import bill by $656 million. The reduction in sugar imports somewhat mediates this ($100 million savings compared to the other scenarios); in addition, less domestic production can free up resources for other sectors. Biodiesel imports increase considerably compared to the other scenarios (especially 4.1 which assumed the status quo for India biodiesel), this has an impact on India's domestic biodiesel production. That is, in scenario 4.1 production increased by 14,622 percent, with changes to trade, production increases by 13,973 percent. The increase in imports also puts less pressure on the price of biodiesel compared to scenario 4.1; in addition, India produces and imports less vegetable oil.

5. Conclusions

The on-set of large-scale biofuel production in the United States and other countries has been named as a contributing factor to the recent bouts of agricultural commodity price volatility. Although biofuels were not the only cause of this volatility, the use of agricultural feedstocks for energy has heightened the awareness of the food versus fuel debate. For countries with large populations, e.g. China and India, the food versus fuel debate takes on added significance if they were to meet their biofuel targets. Rising populations and incomes could increase food demand and bid up food prices, adding biofuel targets on top of that could push agricultural commodity prices much higher. However, if these countries are to use biofuel production as a way of reducing GHG emissions or as a source for energy independence, decisions need to be made on using agricultural feedstocks for food or fuel. Results from this work indicate that there are several options to relieve the pressure on agricultural commodity prices if biofuel targets are to be met. Trade is one source; however, using existing stocks for ethanol or increasing the amount of waste cooking oil for biodiesel provide larger impacts on prices and production. That is, with limits on feedstocks that can be used for biofuel production and limited scope (land, water, etc.,) for expanding conventional feedstock production, these two countries may have to rely on trade and recycling wasted cooking oil to meet biofuel targets in the short-to medium-term. Since domestic production of biofuel is limited, the chances of trade displacing jobs or creating welfare losses are small. In fact, trade in biofuels, along with rules of origin compatible with these countries comparative advantage, may not only spur much needed foreign investment, job/wage growth, but also reduce emissions. Emerging waste management strategies in these countries, especially in urban centers, can be altered to tap the wasted cooking oil from industrial and service sectors. For instance, an incentive such as a liter of blended motor fuel for every 10 liters of wasted cooking oil might motivate intermediaries to facilitate this arbitrage. The public sector has also a food-safety incentive to limit additional food uses of wasted cooking oil. In the long-run, both China and India could make a push to increase biofuel production through unconventional pathways or technological change. All four biofuel scenarios reduce emissions from using traditional transportation fuels; however, the tradeoffs between reducing emissions or increasing energy independence and increasing politically-sensitive food insecurity suggests trade and recycling as near-term options, while investments in technology can address the need in the long-term.

What is touched upon briefly in the results, is the competition for resources among agricultural commodities. Rising populations and incomes mean more land might be needed for agricultural production and producing biofuels will accelerate the demand for agricultural land. In the land-use component of the CGE model, crop land, pasture land, and forest land compete for acreage; crop and pasture land increase in all of our scenarios. This is at the expense of forest land. However, there is another competing issue not captured in this analysis, which is the reduction of GHG emissions. If countries such as China and India use biofuels to help reduce GHG emissions from traditional transportation fuel usage, there is the real risk that land will need to be taken from forests, which could lead to offsetting GHG emissions. Along with the food versus fuel aspect of this analysis, future work should also integrate a complete energy policy framework in their analysis, taking into account all GHG reduction pathways specified in the Paris Agreement.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.biombioe.2017.11.018.

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