

Economic and Environmental Assessment of Expanded Bioenergy Production in China

Yongxia Cai, Robert H. Beach, Birur Dileep
RTI International
Research Triangle Park, NC, USA

Paper to be presented at 18th Annual Conference on Global Economic Analysis,
Melbourne, Australia, June 17-19, 2015

Economic and Environmental Assessment of China's Bioenergy Production and Challenge

Yongxia Cai, Beach Robert, Birur Dileep, RTI International

Objectives

As the second largest oil consumer and the largest oil importer in the world, China's oil consumption and oil imports are expected to continue to rise with the rapid growth of China's economy, especially with the exponential growth in private car ownership. By 2030, 75 percent of China's oil consumption will be imported (IEA, 2008). This heavy reliance on imported oil raises concerns about national energy security, while the large increase in fossil fuel consumption conflicts with domestic and international efforts to reduce greenhouse gas (GHG) emissions. Recognizing these concerns, China has developed policies to promote the use of bioenergy to enhance energy security and to lower air pollution and GHG emissions since 2000. However, due to concerns that increased grain ethanol production was increasing food prices and leading to greater food insecurity, China has moved to restrict the use of grains as bioenergy feedstocks. Instead, they are promoting the use of non-grains that grow on marginal and abandoned lands, such as cassava, sweet potato, sweet sorghum, sugarcane and sugar beets as bioenergy feedstocks. In addition, second generation bioenergy from woody biomass is in the conceptual stage, but is expected to grow rapidly due to abundant biomass resources and supportive governmental policies. With a production of 0.70 billion gallons of ethanol in 2013, China is currently the fourth largest producer of ethanol in the world behind only the United States, Brazil and Europe. The national targets for ethanol and biodiesel production are set to be 3.35 billion gallons and 0.60 billion gallons by 2020, respectively. This paper uses a computable general equilibrium (CGE) model -- the Applied Dynamic Analysis of the Global Economy model focusing on agriculture and land use (ADAGE-ALU), to assess China's bioenergy potential in the short run and long run, including the impact on food prices, land use change and GHG emissions.

Literature Review

Several studies have attempted to assess China's bioenergy potential, technologies and policy incentives for the 2010-2020 period (e.g., Li and Chan-Halbrendt, 2009; Huang *et al.*, 2009; and Yan *et al.*, 2009). Li and Chan-Halbrendt (2009) assesses China's ethanol supply potential by examining potential non-food crops as feedstock; emerging conversion technologies; and cost competitiveness. They find out that sweet sorghum among all the non-food feedstocks has the greatest potential. Based on the estimated available marginal lands for energy crop production, the most likely and the most optimistic ethanol production levels are 19 and 50 million tons by 2020 respectively.

Huang *et al* (2009) has linked GTAP and CHINAGRO to assess the potential impact of China's biofuel development in 2020. They find out to meet the national target in 2020 using non-grains feedstock, production and income of sorghum, cassava, and sweet potato will

increase but the other crops and livestock will decline. The prices for these feedstock rise much higher than the other crops.

Yan, Inderwildi and King (2009) compared different feedstock's emission reduction potential when emission from land use change is included. They find out that the emission reduction potential from grains feedstock is very limited, somewhat higher for high-yielding non-grain crops such as cassava or sugarcane but diminished when forest is cleared to grow the feedstock, substantially higher from cellulosic biomass without disturbing land-use patterns and affecting food supply adversely. Yan *et al* (2012) summarized that China's woody bioenergy development faces unstable feedstock supply, low market interest and investment, inadequate R&D and technology breakthrough, and competition from other forest products, but with abundant resources, technology breakthrough, and national plan of 18.89 million ha of dedicated area for energy forest, it may generate significant ecosystem services such as sequestering CO₂ and reducing soil and water erosion.

However, previous studies have typically focused on the technical potential of bioenergy production with little focus on economy-wide impacts. An exception is Huang *et al.* (2009), which utilizes the GTAP framework to estimate economic impacts. That study does not account for GHG emissions from direct and indirect land use change due to bioenergy production, though.

Methods

In this paper, we use ADAGE-ALU, a recursive dynamic global CGE model, to provide a comprehensive assessment of China's biofuel potential, the impact on China's agriculture and energy sectors, and net GHG emissions, including net emissions associated with land use change. The model projects the global/regional economy, energy, agricultural activity, and biofuels production and land use from 2010 to 2050 at 5-year time steps. Agriculture consists of eight crop categories, one livestock sector, and one forestry sector. Biofuel sectors include seven first generation biofuels and three second generation biofuels (Beach *et al.*, 2011). Land is stratified into five land classes (cropland, pastureland, managed forest land, natural forestland and grassland) and can be converted from one type to another. A nested constant elasticity of substitution (CES) function framework is used to model land-use change, covering both the cost of land conversion and willingness to convert land in the long run. ADAGE has been widely applied for food, energy and climate change related studies, including evaluation of US Renewable Fuel Standards (Cai *et al.*, 2013; Birur *et al.*, 2011), assessment of climate change impacts on agricultural production (Beach and Cai, 2013), and implications of oil prices for global biofuels and GHG mitigation (Cai, Beach, and Zhang, 2014).

In this study, China's non-grain and forest-based bioenergy production are further calibrated using the data in Li and Chan-Halbrendt (2009) and Yan *et al.* (2012). We first explore China's bioenergy production under multiple scenarios using specific categories of feedstocks and those feedstocks in combination to meet the national target in 2020: (1) A business-as-usual scenario (BAU) where China's bioenergy production is held constant at 2010 levels, consisting of

0.57 billion gallons of corn ethanol and 0.13 billion gallons of soybean diesel; (2) A *Non-Grain* scenario where bioenergy production is set to meet the national target in 2020 using only non-grain feedstocks; (3) *Woody-Biomass* scenario where bioenergy production is set to meet the national target in 2020 using only woody biomass feedstocks; (4) *Non-Grain + Woody-Biomass* scenario where non-grain feedstocks and woody biomass are both used as feedstocks to meet the national target in 2020. Second, we relax the national target and let the model optimize bioenergy production from 2010 to 2050 under the purview of the whole economy, considering factors such as price, demand, supply, and trade together. The *BAU* case holding China's bioenergy production constant at 2010 levels during 2010~2050 is used to do the comparative study.

Results and Conclusion

As expected, with persistent economic growth and continued improvement in land productivity and energy efficiency, China's agricultural production continues to increase, along with rising food and energy prices as well as GHG emissions during the period of 2010-2020 in the *BAU* scenario. When non-grain bioenergy is used to meet the national targets in 2020, price and total production of non-grain commodities increase significantly more than in the *BAU* case, while the grains and other agricultural commodities decline slightly than in the *BAU* case. Comparing the *Woody-biomass* scenario with the *BAU* case, we find that agricultural production including both grains and non-grains commodities declines slightly while price rises slightly, as less land is converted from forestry land to cropland. When non-grains and woody biomass are both used as bioenergy feedstocks, the change of price and production for both grain and non-grain commodities display similar directions as in the *Non-Grain* case, but the magnitude is smaller. With the national target, refined oil consumption and price both fall in all cases relative to the *BAU* case. Even when emissions from land use are included, there is a slight decline in overall GHG emissions for these scenarios compared with the *BAU* case, with the largest decline in the *Woody-Biomass* -case, followed by the *Non-grain + Woody-Biomass* case, then by the *Non-Grain* case. When bioenergy production is determined by the market, bioenergy production is less than the national target in 2020, but rises rapidly after 2030, especially from woody-biomass bioenergy, and further brings down the GHG emissions. This study provides a comprehensive picture regarding the potential for future expansion of China's biofuel production and the associated tradeoffs.

Reference

Tian, Y., L. Zhao, H. Meng, L. Sun, J. Yan. "Estimation of un-used land potential for biofuels development in (the) People's Republic of China", *Applied Energy*, 86 (2009), pp. S77–S85.

- Li, S., C. Chan-Halbrendt. "Ethanol production in (the) People's Republic of China: Potential and technologies", *Applied Energy* 86 (2009) S162–S169.
- Yan X., O.R. Inderwildi, D.A. King. "Biofuels and synthetic fuels in the US and China: A review of Well-to-Wheel energy use and greenhouse gas emissions with the impact of land-use change", *Energy Environmental Science*. (2010)3, 190-197.
- Huang, J., H. Qiu, Y. Jun, "Biofuel Development in China and the Potential Impacts", 7th Asian Society of Agricultural Economists (ASAE) International Conference, Oct 13-15, 2011, Hanoi, Vietnam.
- Yang, J., G. Dai, L. Ma, L. Jia, J. Wu, X. Wang, "Forest-based bioenergy in China: Status, opportunities, and challenges", *Renewable and Sustainable Energy Reviews* (2013), 8, P478–485.