Energy Economics 65 (2017) 148–160

Contents lists available at ScienceDirect

Energy Economics

journal homepage: www.elsevier.com/locate/eneeco

Impacts of US biodiesel mandates on world vegetable oil markets

Jingbo Cui [a,*,1], Jeremy I. Martin [b]

[a] Mailbox No. 11-12, School of Economics and Management, Wuhan University, Wuhan 430072, China
[b] Clean Vehicles Program, Union of Concerned Scientists, Washington DC 20006, United States

ARTICLE INFO

Article history:
Received 31 August 2015
Received in revised form 11 April 2017
Accepted 18 April 2017
Available online 1 May 2017

JEL classification:
Q2
H2
F1

Keywords:
Biofuel policies
Diesel taxes
Mandates
Renewable fuel standard

ABSTRACT

In this paper we seek to understand the impact of expanded use of soybean oil biodiesel to address biofuel mandates on global vegetable oil markets, and in particular on the demand for palm oil. An open-economy equilibrium model is derived to investigate the market effects of biodiesel expansion on related energy and vegetable oil markets. The model is calibrated to represent the recent benchmark data in calendar year 2014. The simulation estimates suggest that the expanded use of soy oil for biodiesel in the US will have considerable impacts on world vegetable oil markets. The majority of the vegetable oil replacement is likely to occur through substitution of palm oil under a wide range of plausible elasticity values on the demand for vegetable oil and the demand substitution between soy oils and palm oils.

1. Introduction

Under the recent Renewable Fuel Standards (RFS) program, the US Environmental Protection Agency (EPA) is finalizing the volume requirements for biomass-based diesel in calendar years from 2014 to 2017. The US biodiesel mandates grow steadily, increasing every year from 1 billion gallons (BG) by 2012 up to 2 BG by 2017. Driven by the rising mandates, biodiesel production in the US rises substantially from less than 0.5 BG in 2007 to 1.24 BG in the end of 2014. The majority of U.S. biodiesel has been produced from soybean oil, which is crushed from soybeans. On the one hand, increases in uses of soy oils for biodiesel could come primarily from reductions in the use of vegetable oils for food and feed purposes, leading to a so called food versus fuel trade-off that raises ethical concerns about the consequences of expanded soy biodiesel uses. On the other hand, the expansion of oilseed production is a major driver of global deforestation, calling for the life cycle re-assessment of GHG emissions saving for biodiesel from different feedstocks and pathway.[2]

The purpose of this paper is to provide an economic analysis of the incremental biodiesel mandate on related world vegetable oil markets, and its welfare implications on the US economy. Facets of this topic have been the subject of a few studies. Drabik et al. (2014) setup a partial equilibrium model, linking oilseed feedstocks with biodiesel market. They examine the impacts of exogenous crude oil shocks on world oilseed markets (i.e., soybeans and canola) through transmission of the biodiesel-feedstock linkage. Their analytic results show that the impacts depend on relative elasticity of world meal demand and canola supply. Kruse (2011) looks at two possible future scenarios regarding the opportunity of biodiesel production and the expansion of biodiesel mandate given current global economic growth and crude oil price projections. The US biodiesel module used in his work is a partial equilibrium model with behavioral supply and demand equations and an endogenous biodiesel price. To meet 3.3 BG of biodiesel mandate, about 80% of the increase of feedstock comes from soybean oils (31%), corn oils (22%), and palm fatty acid distillate (26%). Animal fats, yellow grease and other grease together supply another 16%, while the remaining is refined from canola and palm oil.

Earlier studies that are the basis for the administration of lifecycle based biofuel policies in the United States and California have predicted a limited impact of US soy oil consumption on vegetable oil production. The EPA study finds that expanding production of soy biodiesel by 540 million gallons would primarily lead to reduced use of vegetable oil and expanded soy oil production, and would have a modest impact on palm oil production (CARD, 2009). For every additional 1000 metric tons of soy oil used to produce biodiesel in the U.S. relative

* Corresponding author.
E-mail addresses: jbcui2013@gmail.com (J. Cui), JMartin@ucsusa.org (J.I. Martin).

[1] Jingbo is grateful to the National Natural Science Fund of China (No. 71603191) for financial support. The Union of Concerned Scientists acknowledges The David and Lucile Packard Foundation for supporting this work.

[2] The two largest sources of vegetable oil, soybeans and palm oil, are both associated with substantial, and quite distinct patterns of deforestation. While soybean expansion has happened primarily in South America where it has competed with pastureland and forest, oil palm expansion has occurred in Southeast Asia, where its expansion has been associated with drainage and deforestation of peat forests.

http://dx.doi.org/10.1016/j.eneco.2017.04.010
0140-9883/

to the baseline, soy oil production expanded by 288 metric tons, palm oil increased by 79 metric tons, rapeseed oil increased by 51 metric tons, other sources of oil increased by 55 metric tons, and 526 tons were not replaced, as non-biodiesel vegetable oil consumption dropped in response to higher prices. Other projections (Birur et al., 2009; Hertel et al., 2010b; Taheripour et al., 2010; Beckman et al., 2012), in particular the GTAP study used by the California Air Resources Board (Tyner et al., 2010), do not differentiate separate sources of vegetable oil, although they do have a detailed treatment of oilseed meal markets required to accurately capture the changes on the meal demand side.

A number of studies about land use changes driven by US biofuel production have placed less emphasis on oilseeds (Elobeid et al., 2007; de Gorter and Just, 2009; Hayes et al., 2009; Keeney and Hertel, 2009; Hertel et al., 2010a, 2010b; Fabiosa et al., 2010; Timilsina et al., 2010; Chen et al., 2011; Villoria and Hertel, 2011; Khanna et al., 2016), because these have been expected to play a relatively minor role in U.S. biofuel expansion, which has been expected to come primarily from either corn, or ultimately from biomass.[3] However, events of the last few years have shown the potential for biodiesel and vegetable oil based renewable diesel to play a substantially larger role than previously expected. Recent efforts to evaluate the impact of U.S. biodiesel production on land use change and associated carbon emissions have led to considerable improvements in economic models, taking into careful consideration of the demand dynamics of animal feed markets (Beach and McCarl, 2010; Taheripour et al., 2011, 2013). However, an area which has been examined less carefully is the potential for other consumers of vegetable oil, outside the fuel and animal feed sector, to switch to other sources of vegetable oil. Biodiesel demand drives a wedge between demand for oil and demand for protein meal. Given that the changes in demand for oil can be quite large, there is a potential for a significant imbalance to arise. In 2013 the use of preliminary data suggests that biodiesel use grew by approximately 40%, of which more than half came from soybean oil. The additional 800,000 metric tons of soy oil being used for biodiesel represent a large and rapidly growing share of U.S. soybean oil production, and depending upon pending legislative, regulatory and judicial decisions, the potential remains for policy driven biodiesel demand to surge again in coming years (Irwin and Good, 2013). Rebalancing demand for oil and protein meal will lead to either a dramatic reduction in consumption of vegetable oil in other sectors or alternatively substitution of other sources of vegetable oil with lower meal to oil ratios. To the extent the latter occurs, increasing demand for soy biodiesel will play out in expanded palm production rather than expanded soybean production. This will in turn drive land use changes in different regions of the world, and is thus important to accurately model land use change associated with biodiesel production.

In this paper we consider to what extent additional vegetable oil demand will alter production of alternative sources of vegetable oil, particularly palm oil. Our analysis considers the two largest global sources of vegetable oil, which represent the extreme ends of the spectrum: soybeans, for which the primary economic value is the protein meal, and oil palm, for which the primary economic value is the vegetable oil. Palm oil is not the only alternative source of vegetable oil to soy oil, but it is particularly important both because it accounts for 1/3 of world vegetable oil production and is the fastest growing source of vegetable oil on the global marketplace (USDA, 2006), and because in contrast to soybeans and to a lesser oil extent rapeseed or canola, palm oil derives most of its value from the oil, rather than a protein meal byproduct, and as such is likely to be more responsive to changes in demand for vegetable oil.

This paper constructs a simple multi-market equilibrium model that applies and extends the analytic setup in Cui et al. (2011). The extended model incorporates the joint product feature of the oilseed crushing technology. We use this model to provide both qualitative and quantitative estimates of increasing biodiesel mandates on related energy and vegetable oil markets, in particular, palm oil. The model specifications allow endogenous determinations of equilibrium quantities and prices for crude oil, biodiesel, agricultural feedstock. Moreover, the model considers a scenario that allows the US biodiesel production to use imported palm oils as alternative feedstocks, while assuming perfect substitution between soy oil-based biodiesel and palm oil-based biodiesel. We calibrate the model to represent a recent baseline calendar year 2014. By varying the increment of biodiesel mandates proposed in recent RFS requirements, we explore how the increasing mandate affects equilibrium quantities and prices of world vegetable oils. We then investigate the robustness of our conclusions by varying with the values of two sets of parameters: one is the unconditional elasticity of demand for vegetable oils, and the other is the demand elasticity of substitution between soy and palm oils. A Monte Carlo simulation on selected key parameters is conducted as well.

Our results show how the impacts of increasing biodiesel production on soy meals and oils are related to the impacts on palm oil, depending upon the joint production technology of the oilseed crushing industry, the relative elasticity of world demand and supply of palm oils, and the demand elasticity of substitution across alternative vegetable oils. The simulation estimates suggest that the expanded use of soy oil for biodiesel in the US will have considerable impacts on world vegetable oil markets. The majority of the vegetable oil replacement is likely to occur through substitution of palm oil under a wide range of plausible elasticity values.

The remainder of this paper is organized as follows. The next section presents the analytic model setup that links the oilseed crushing industry with the biodiesel refining sector. The model calibration is summarized in Section 3. Simulated results about the market impacts of the increasing biodiesel mandates are shown in Section 4. The last section concludes the paper.

2. The model

The model is a stylized economy with three basic endowments: a numeraire good, agricultural feedstock, and crude oil. There are two main categories of agricultural feedstock: soybean, and palm oil. Soybean oil, which is crushed from soybean, could be used to produce biodiesel. The primary product crude oil is refined into diesel and others that are grouped as petroleum by-products. Transportation fuel is obtained by blending the intermediate products biodiesel and fossil fuels. Biodiesel from soybean oil together with its close substitute diesel are two complementary components of the diesel composite purchased by consumers if biodiesel mandates are binding.

2.1. Production

We construct a simplified multi-market equilibrium model with two regions: the US and the Rest of World (ROW). To capture the status quo that the US does not produce palm oil, we assume away its domestic production. Throughout this paper, we maintain the assumption that there is no international trade of biodiesel. In addition, we postulate that there is trade in crude oil, but no trade in the refined fossil fuels, which is a fair approximation of the status quo.[4] The assumption of constant returns to scale and no capacity constraints on the oilseeds crushing technology introduced shortly makes the interregional distribution of crushing soybeans undetermined in the equilibrium. Hence, we only consider the trade of soybean oils and meals instead of beans.[5] To sum

[3] Biofuel production in the European Union (EU) has been primarily through expansion of biodiesel, and analysis of land use changes driven by EU mandates has focused much more extensively on the fluidity of different vegetable oil sources (Timilsina et al., 2010; Al-Riffai et al., 2010; Laborde, 2011).

[4] The net trade of refined petroleum only accounts for less than 5% of total consumption over the period 2007–2013.

[5] Alternatively, one could allow beans to be tradable, but not for soy oils and meals. In this scenario, however, the excess supply of meals, as a result of the increasing crushed of beans, may cause a substantial drop in the domestic price of meals.