ARTICLE IN PRESS

Renewable and Sustainable Energy Reviews (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Economic analysis of an aviation bioenergy supply chain

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ARTICLE INFO

Keywords:
Aviation
Biofuels
Camelina
Energy policy
General equilibrium
Oilseeds

ABSTRACT

This study develops a regional economic model that can mimic stages of a potential aviation fuel supply chain based on the oilseed camelina. A general equilibrium model is developed that accounts for key sectors of the supply chain, and is parameterized using detailed data for the Pacific Northwest region of the United States. Model scenarios are developed to evaluate the potential effectiveness of policies that would promote the development of the supply chain. While the existing low price of conventional fuel makes camelina-based fuel economically infeasible at present, the supply chain could be viable if consumers, e.g. airline passengers, are willing pay more to use the biofuel, such as if they perceive an environmental benefit from it. Alternatively, if use of the oilseed is consistent with the energy policy priorities of policymakers, one of the following approaches could potentially work: a 17% subsidy on the alternative fuel, a 20% tax on the conventional fuel, or a combination 9% subsidy on the alternative and 9% tax on the conventional fuel. Implications for economic efficiency, regional employment, and economic welfare are quantified.

1. Introduction

This study concerns the development of a new bioenergy supply chain for the aviation sector of the Pacific Northwest region of the United States. The focus is on the policies and price signals necessary to induce a new market channel to develop, and on the implications for the efficiency of resource allocation. A general equilibrium economic model with explicit representation of key sectors is developed and applied to aviation fuel made from oilseeds such as camelina. It can be processed into a high grade bio-based jet fuel for military and commercial purposes using approaches such as a Hydroprocessed Esters and Fatty Acids (HEFA) process (Bauen et al. [1], Shonnard et al. [2], IATA [3], and Natelson et al. [4]).

Interest in this potential bioenergy resource has grown in recent years. For example, the number of airlines which have used a blend of this alternative fuel for a commercial flight has risen to 21 (IATA [3]). Interest is also strong among military agencies, such as the U.S. Air Force, and operators of commercial airports, including those of Portland and Seattle. These institutions are reportedly interested in using U.S.-sourced biofuels, again for supply diversification, and perhaps for perceived environmental reasons, such as a reduction in net greenhouse gas emissions. Additional support has come from the U.S. Environmental Protection Agency who has declared that aviation biofuel – biojet, in industry parlance – is eligible for Renewable Identification Numbers that can be traded on the open market. This has further solidified the long term prospects for this new bioenergy supply chain (IATA [3]).

At the other end of the supply chain are oilseed processors and refiners, and ultimately, farmers who would need to plant the appropriate oilseeds. Camelina, for example, is argued to be ideal in the Pacific Northwest, where its cultivation need not displace other crops grown for food when incorporated into a wheat-fallow rotation (Stein [5]). Although currently grown on less than 50,000 acres in the United States, acreage could potentially be expanded by three to four million acres without adversely impacting food prices (EPA [6], Winchester et al. [7]). It also has low input requirements, is suitable for marginal soils, and has natural competitiveness with weeds (Putnam et al. [8], Hulbert et al. [9]).

Despite the theoretical potential and technical plausibility of this alternative supply chain, the economics of how the market might work are less clear. There are public good aspects to the problem, meaning that the private sector, by itself, may not make the necessary investments. Interactions up and down the supply chain must be considered, including the incentives of a range of different economic agents who may have competing interests. Farmers, for example, are incentivized by a high price for camelina, while refiners are incentivized by a low price. Whether prices can be found that satisfy all supply chain participants, simultaneously, is an empirical question that can be addressed in part by economic modeling.

To shed light on this problem, a general equilibrium economic

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http://dx.doi.org/10.1016/j.rser.2016.12.036
Received 9 May 2015; Received in revised form 20 April 2016; Accepted 6 December 2016
1364-0321/

model is developed in this study that simultaneously accounts for a number of sectors key to the analysis. This general type of model is part of a venerable tradition in economics, and has been used to study biofuel energy policy (Cansino et al. [10]). It combines mathematical representation of the incentives and constraints faced by all of the economic actors in the system. To make the model useful for policy, it must be made to replicate, that is, its parameters must be calibrated such that the model can reproduce baseline data for the region in an appropriate recent time period. Parameters of the model are calibrated primarily using highly detailed IMPLAN [11] data for the Pacific Northwest region (Oregon, Washington, and Idaho) of the United States. These data account for trade and transfers between hundreds of economic sectors within the region, including between the aviation, processing, and farming sectors.

Once parameterized and validated, the model is used to illustrate the mechanisms that could make this new bioenergy supply chain economically feasible. These include non-policy as well as policy instruments such as subsidies and taxes, including a tax-cum-subsidy approach. A suitably motivated government could conceivably take the estimates of this study and use them to guide policies that would facilitate the emergence of an aviation biofuel supply chain in the Pacific Northwest.

Unlike related studies such as Natelson et al. [4], Tabatabaie and Murthy [12], and Winchester et al. [7], the present study does not emphasize the engineering aspects of biofuel production, the change in greenhouse gas emissions for conventional versus alternative fuels, or quantify the potential security benefits of using alternative fuels. For example, Natelson et al. [4] provides a techno-economic analysis of alternative fuel production based upon oilseeds such as camelina. Relative to this study, they provide much more detail on the engineering requirements for alternative refinery operations, but less detail on different aspects of the supply chain, including the welfare consequences of alternative tax and subsidy policies that could make biojet comparable in price to conventional fuel. The study at hand additionally emphasizes labor market impacts and a range of macro-economic outcomes.

A special focus is on whether increased demand for oilseeds can be met by local sources, as opposed to sources outside a region. One of the selling points of oilseeds – camelina in particular – is that it can be a "home grown" source of fuel with very low opportunity costs of production. Yet even if the oilseed feedstock is produced by local farms, this may not imply that the processing will occur within the region. Likewise, if the processing is done within the region, the oilseed feedstock could perhaps be procured most efficiently from *outside* the region, such as from Canadian farmers, thereby diluting the "home grown" nature of the energy resource from the viewpoint of U.S. policymakers.

To address these issues, the study explicitly models the separate stages of a vertical supply chain, including sourcing from inside and outside a region of the United States, and from outside the country. In this sense, the study complements Winchester et al.'s [7] analysis of alternative fuels for the aviation industry. Their study uses a global general equilibrium model, and considers other advanced biofuels such as biomass-based diesel and grain-based ethanol cellulosic fuels. The study at hand considers a particular supply chain, distinguishing oilseed production from processing and refining, and emphasizes the Pacific Northwest region, where oilseeds can be integrated into a wheat-fallow operation with little or no impact on wheat supply (Stein [5]). This study also considers different policy instruments, including a tax-cum-subsidy that can minimize the distortion of economic incentives in multiple markets.

Another unique aspect of this study is that model parameters are validated using historical price and quantity data for oilseeds. This goes beyond simply calibrating the model to IMPLAN input-output social accounting data. In this study, actual year-to-year price movements are compared to those which arise from model simulations representing similar shocks, following pioneering techniques introduced in Valenzuela et al. [13]. This aspect of the study is novel in the general equilibrium literature and assists the reader gauge the reliability of the results.

The study also complements work by Diebel and Ball [14], Walsh [15], and Stein [5]. Building on the first two studies, Stein estimates potential supply curves for camelina in Oregon, Washington, Idaho, and Montana with a break-even price approach. Stein's results suggest that given current market conditions, the supply in the Pacific Northwest will not be enough to meet biofuel targets without an increase in promotion, most likely by government. This finding serves as one motivation for the study at hand. Unlike the approach proposed here, Stein uses a partial equilibrium framework and looks mainly at adoption by farmers, as opposed to the links between different market players. He does not examine policy, the potential for inter-regional trade, labor markets, or any of the macro-economic aspects considered here.

The study is also complementary to McCullough et al. [16], who assess the potential for biofuels production in Washington state. As with many other studies, they find that some form of government intervention is likely to be needed to "jumpstart" the system. The study at hand is distinct in that it considers a larger geographical area, recent developments with respect to aviation biojet demand, and a wider variety of policies at different stages of the supply chain.

To preview some of the conclusions, this study finds that the new bioenergy supply could be made feasible, or at least price competitive, through a number of particular policy mechanisms. Unless a segment of consumers can be induced to pay extra for use of biojet, one of the following policies would provide the incentive structure to facilitate market development: a 17% subsidy on the alternative fuel, a 20% tax on the conventional fuel, or a combined 9% subsidy on the former and 9% tax on the latter. The latter, so-called tax-cum-subsidy approach provides a "double dividend" in the sense that it combines a targeted tax on conventional fuel, with a targeted subsidy on the alternative fuel, so as to be relatively revenue-neutral and to have smaller distortions on other markets.

The remainder of the study is organized as follows. The next section describes the modeling approach taken, addressing the general problem of how to model a market channel for a new product that is not yet established. Since the model shares many features from other established computable general equilibrium models, changes that are unique to this study are emphasized, with separate sections describing the regional adaptation of the modeling framework, the data, calibration of model parameters, and validation of key parameters. Subsequent sections, in turn, examine how the scenarios are developed, and the results. Five different cases are analyzed, each of which shed light on viable options for development of a regional supply chain for biofuels. The final section concludes.

2. Modeling approach and data

A diagram of the methodology for the study is in Fig. 1. At the top of the figure are two boxes; the left represents the theoretical economic model, which is a mathematical representation of the behavioral objectives and responses of all decision-makers including government. The theoretical model accounts for numerous economic features including taxes, subsidies, and the other policy instruments to be discussed below. The theoretical model is combined with a social accounting matrix (SAM) to create a calibrated economic model. The SAM itself is created using IMPLAN (2012) data to numerically represent trades and transfers between producers, buyers, households, and government. The SAM also traces the flows of tax revenues, government spending, exports, and imports. Finally, the calibrated model is shocked with a number of policy simulations to generate new equilibrium values of all endogenous variables. These are compared to the original baseline values to evaluate different policy measures.