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Awaiting Takeoff: New Aviation Fuels from Farms and Forests

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Imagine flying across the United States on a plane powered by jet fuel derived from trees and oilseeds that grew 35,000 feet below. Imagine further that harvesting those trees and oilseeds did not reduce output of other products grown in rural areas. Finally, imagine that instead of being viewed as "flyover country," many of these rural areas had new jobs and economic activity from converting biomass into jet fuel. At present, this entirely plausible scenario remains unfulfilled. The reason is that bio-based jet fuel, or biojet, is presently not cost-competitive with traditional fossil fuels, although there is greater parity when societal costs and benefits are taken into account. This article reviews recent evidence supporting these conclusions. First we provide background on why there has been strong interest in renewable aviation fuels.

A Desire to Diversify Away from Conventional Jet Fuel

Modern jetliners are marvels of performance, safety, and efficiency, but their use of kerosene-based jet fuel has environmental and other drawbacks. The international aviation industry has long been criticized as being a laggard in global efforts to decarbonize the world economy. At present, aviation accounts for 4% of global carbon emissions. However, air travel is set to grow rapidly in the future. Meanwhile, other industries are increasingly shifting to less carbon-intensive energy sources (Keen and Strand, 2007). For these reasons, the 4% share of global carbon emissions is projected to grow steadily.

To address this issue, the International Air Transport Association (IATA)—a trade association consisting of 274 of the world's airlines—has committed to reducing carbon emissions by 50% by 2050 compared to the 2005 level (IATA, 2009; Chu et al., 2016). A primary pathway for achieving the reduction is the use of bio-based renewable fuels such as biojet (IATA, 2009). Relative to conventional, kerosene-based fuels, biojet may reduce aviation emissions by 10%–50% depending on the feedstock, the production technology, and the emissions from land use change (Chu et al., 2016; Tabatabaie and Murthy, 2017). In addition to environmental concerns, adopting biojet would diversify the fuel mix, thereby reducing exposure to uncertain world supplies (IATA, 2009). This rationale has been cited by commercial aviation providers and military agencies.

Biojet is not in widespread use, but it is also not a novelty. At least 20 commercial airlines have experimented with biojet for commercial flight, and interest is also particularly strong among military agencies, such as the U.S. Navy (a large consumer of jet fuel on aircraft carriers). Operators of commercial airports—such as those in Portland, Oregon, and Seattle, Washington—are highly receptive to biojet; their primary interest appears to be its reputation as a "home grown" and environmentally benign fuel source.

A biojet supply chain, in turn, could help rural communities that are traditionally dependent on farming or forestry. A number of studies funded by the U.S. Department of Agriculture (USDA) over the last 6 years have examined how this could work. The starting point of such studies was that additional uses for rural resources could be a win–win situation across the United States, diversifying energy sources while supporting small communities and rural populations.

Below, we investigate two such scenarios: One is the introduction of the oilseed camelina into a dryland cropping system. The other is the use of logging slash (harvest residue) from forestry operations. Both scenarios concern the western United States, with the former occurring primarily on private land and the latter occurring primarily on public land. The lessons learned, however, are more broadly applicable to the rest of the United States.

From Farm to Flight: The Case of Camelina

The oilseed camelina has several desirable qualities as a feedstock, including low moisture and input requirements, suitability for marginal land, and natural competitiveness with weeds (see box 1). At present, approximately 50,000 acres of camelina are produced in the United States as a cover crop in low-rainfall wheat–fallow rotations. Studies show that acreage could be expanded to 3–4 million without adversely affecting food prices (EPA, 2013; Winchester et al., 2013; Gardebroek, Reimer, and Baller, 2017). This characteristic is important, as the potential for raising food prices is a major criticism of other biofuel feedstocks (Barham, Mooney, and Swinton, 2016).

Reimer and Zheng (2017) modeled the production of camelina as a biojet feedstock using a computable general equilibrium model. The model represented the western regional economy as a system and comprehensively represented the supply chain from camelina to aviation services (see box 2). The approach was detailed enough to account for camelina's co-products, including meal, which can be fed to livestock, as well as international trade, input suppliers, camelina oilseed processors, refiners, and final consumers, including the military and private aviation industry. The approach also accounted for potential deadweight losses associated with policy instruments that the federal government might employ to facilitate creating a biofuel supply chain.

The study found that the existing low price of conventional jet fuel makes camelina-based biojet economically infeasible at present. However, the supply chain could be viable in a market context if consumers (e.g., airline passengers) were willing pay more to use biojet. Consumers may be willing to do so if they perceive an environmental or some other benefit from substituting biojet for conventional fuel. Airlines could then use the proceeds to offset the higher cost of biojet. However, the available evidence suggests that this possibility is unlikely. As a result, the study considered other potential approaches to jumpstart a

Box 1: How to Get Jet Fuel from Trees and Crops

Wood is a combination of cellulosic sugars and lignin. Lignin is the glue that holds the tree together and gives it stiffness and strength—qualities needed for many applications, but not when we're trying to get at the sugars. When fuel is made from wood, lignin presents a problem because it resists breaking down. Pretreatment is required to separate the sugars from the lignin. Many proprietary and experimental pretreatments have been developed to complete this step. Once sugars have been isolated, numerous pathways exist for creating fuels, including converting the sugars to isobutanol (similar to the intermediate ethanol generated from agricultural crops). Isobutanol can then be made into multiple products, including biojet, solvents, and polymers. Frequently, the production of valuable co-products is essential for feasible biofuel production. In the case of camelina, jet fuel from bio-based sources that is certified for use in commercial aviation is generally created using a HEFA (hydroprocessed esters and fatty acids) process. A catalytic process is used to convert oils from the feedstock into the raw purified oil and into biojet that meets or exceeds current fossil jet fuel standards.

Box 2: Two Ways to Model Complex Economic Systems

It may seem impossible to model a market that does not yet exist, but economic theory combined with relevant data provides a guide for doing so. In the camelina study, a general equilibrium model was used in which all sectors of the economy are represented and the behavior of people from citizens to farmers is modeled. Total societal costs and benefits are calculated. In the forest residues study, a dynamic optimization model was used that focused on the forest products sector. In this model, supply (trees ready to harvest) and demand (mills or other processing centers) are balanced over time to maximize total consumer and producer surplus, a measure of total benefit. The model incorporates changes in forest supply over time as trees grow and are replanted, costs associated with harvesting and transporting raw materials, and costs of production at the mill. The model adjusts to changes in final consumer demand for mill outputs like lumber. Both approaches use detailed recent data and were programmed and solved using GAMS, the General Algebraic Modeling System (GAMS, 2013).

biojet supply chain, including taxes and subsidies. Before such policies are considered, some background on the other feedstock is first provided.

From Forest to Flight: The Case of Harvest Residues

In the western United States, the majority of commercially harvested timber is converted to logs and then either exported or processed into lumber at local sawmills. A great deal of residual harvest material, including tree tops and limbs, is typically not worth the cost to remove and so is left on site, either scattered in the woods or in large piles. This material gets in the way of tree replanting activities and is also a fire hazard. In addition, the lack of a market for material smaller than sawtimber size (such as small, suppressed trees in the understory) limits the economic feasibility of restoration management or of wildfire risk–reduction activities.

The harvest residues therefore create a problem. Crandall et al. (2017) considered a potential remedy, simulating the impacts of a biojet plant that utilizes woody biomass in western Oregon. The creation of a market for harvest residues—some of which could be pre-processed in small, dispersed facilities—would have the potential to enhance financial returns to landowners and be a boon to rural communities that have experienced wide swings in harvest activity over the last 20 years. The study found that given the current market price for logging harvest residues, however, establishing and operating small processing facilities in rural areas is economically infeasible. Similar to the case of camelina, there is presently a cost disadvantage of biojet made from harvest residues relative to that of conventional jet fuel.

If made from camelina, biojet's production costs are 45–69 cents more per gallon than kerosene-based fuel (Winchester et al. 2013; Chu et al., 2016; Reimer and Zheng, 2017). If made from woody biomass, the gap is larger still. For woody residues, the major cost of production is in gathering and transporting the material. Depending on the circumstances, the price paid for harvest residues would have to be as high as $75 per dry ton—over twice the current price—to justify the expense of delivering harvest residues to processing facilities in rural locations.

Policies to Make Biojet Competitive

It is clear that without government intervention, biojet made from camelina or woody biomass is financially unsustainable at present. In light of the potential public good aspects of these feedstocks, however, recent research has considered policy interventions that would enable the development of biojet supply chains. In the case of camelina-based biojet production, the following approaches were found to make biojet cost-competitive with conventional jet fuel: a 17% subsidy on biojet, a 20% tax on conventional fuel, or a combination 9% subsidy on biojet and 9% tax on conventional fuel (Reimer and Zheng, 2017). These policy solutions have a number of problems, however.

One problem with the 17% subsidy is that it is a particularly expensive approach and entails a higher excess burden associated with the taxes necessary to fund the subsidy as compared to other approaches considered. This form of policy intervention would only make sense if biojet were viewed as providing a significant public good. Other ways to achieve cost parity with conventional fuel include a 20% tax on conventional aviation fuel (Reimer and Zheng) or imposing a national carbon price of $55/ton (Chu et al., 2016). While these approaches have merit, they would greatly raise the cost of air transport and seem unlikely given current political considerations. In addition, Reimer and Zheng highlighted the difficulty of determining the optimal carbon tax. Policy makers would need good information about cross-price elasticities of demand since the model appeared to be sensitive to some of these details. Chu et al. (2016) similarly found that biojet feasibility is highly sensitive to fuel product prices and feedstock prices. Given this sensitivity, it may be difficult for policy makers to determine the optimal tax or subsidy.

One other possibility considered by Reimer and Zheng was a combined 9% subsidy on biojet and 9% tax on conventional fuel. This would also make biojet comparable in cost while having some advantages relative to the other policy interventions. One advantage is that it is revenue neutral, meaning there is no net cost to taxpayers. Another advantage is that the model predicted that this approach would have favorable macro-economic outcomes in the Pacific Northwest where camelina can be grown, including moderate net increases in regional economic activity, jobs, and regional economic welfare. This is possible in part because the federal government already imposes a wide array of taxes and subsidies in these sectors. These distortions are captured in the data that underpin Reimer and Zheng's model and suggest that the existing air transportation sector is not necessarily *first-best* optimal from an economic efficiency standpoint (see, e.g., Coady et al., 2017). Starting from the existing *second-best* economic environment, the taxes and subsidies considered as part of the simulation offset some initial distortions and lead to a slight rise in economic activity. Despite this positive result, however, it should be acknowledged that it can be very difficult to correctly specify and implement such policies in the real world.

The forestry example has similarities to and differences with the camelina case. Harvest residues can become quite costly to transport when logging occurs in remote, mountainous terrain. For this reason, Crandall et al.'s (2017) forest industry model paid particular attention to the role of space and geography. Their first scenario assumed the offered price for harvest residues was sufficiently high to be consistent with the financial viability of a biojet supply chain, including processing plant, in the region. They found that the most economically feasible processing plants would be located near harvest areas that are already highly active, thereby muting the benefit to rural areas as a whole. In turn, the high feedstock prices necessary for the economic feasibility of remote processing centers would render the processed product (biojet) too high to be competitive with conventional fuels.

Another scenario considered the possibility of increasing harvests on public lands by state or federal agencies. Many rural communities in the West have experienced a steep decline in the amount of material harvested off public lands. As a result, higher public lands harvest is often sought as a solution to economic struggles in these rural areas. In the study by Crandall et al. (2017), however, increases in the amount of harvest (and thus supply of harvest residues) on public lands didn't change the basic outcome: For any given scenario, facilities were more likely to be economically feasible in areas that already had high harvest activity. So while one goal of establishing biojet supply chains from harvest residues is rural development, the most remote locations appear to be the *least* economically feasible places in which to establish processing centers.

Other Effects on Rural Development

Despite important geographical differences (including whether land is privately or publicly held), one similarity among the rural areas examined in the studies is that they are all struggling economically. As employment in the agricultural and forest industries has declined over time, lower incomes and worker out-migration have become an issue in many natural-resource-dependent areas. When studies consider these issues, they have found that developing markets for biojet would seem to deliver on one of its promises—that it would aid *some* rural areas through increased economic activity.

In the case of camelina, the combined 9% subsidy on biojet and 9% tax on conventional fuel had the most favorable region-wide macro-economic outcome of any scenario considered. As modeled, it would increase gross regional product by as much as 2.1% and would increase the number of regional jobs in oilseed farming by 3.6% and jobs in oilseed processing and refining by 13%. In the case of harvest residues from logging, operating a rural processing center could generate 20 full-time jobs at full capacity. This job impact would be higher once one accounts for increased harvesting employment to gather and deliver the feedstock, as well as other multiplier employment effects. However, these impacts have limited geographic distribution.

Other potential public benefits are harder to quantify but are important to point out nonetheless. While using forest harvest residues as a feedstock was generally less cost feasible than camelina, it offset this with potentially higher social benefits. Many western forests have historically high levels of wildfire risk due to a mix of past policies, land management activities, and settlement patterns. Developing a market for logging harvest residues could remove dangerously flammable material from these forests.

Another public benefit may be a dampening of the boom-and-bust nature of natural-resource-based economies. A more diverse, steady demand for natural resources may incentivize investments in natural and built capital such as forests, agricultural lands, and buildings. It may also help stabilize labor markets and the rural tax base, which could lead to greater human and social capital among rural citizens. Over the long run, this may also reduce the amount of social services and welfare subsidies going to these areas.

Should We Devote Resources toward These Alternatives?

By itself, economic research cannot determine whether society should devote resources to facilitating new biojet supply chains. On balance, the new research shows that substantial taxpayer assistance will be required, either in the form of direct subsidies to the industry or through taxes on conventional fuels and/or carbon. If designed right, both the direct and excess burden of the associated taxes can be minimized, but such policies are nonetheless likely to be politically infeasible if the main public benefit of biojet (that is, reduced carbon emissions) is captured primarily by future generations.

Policy makers should also know that trying to target certain regions for rural development may have unintended consequences. One of the models reviewed here suggested that the camelina supply chain could be met to some extent by production from Canada, thereby diluting U.S.-specific benefits and possibly the support of citizens and policy makers in the targeted areas. In the case of forest harvest residues, some, but not all, towns may develop intermediate processing centers; most rural woods communities would likely see no benefit. So neither camelina or harvest residues from logging are a “magic bullet” for improving the economy and well-being of citizens of rural places.

To sum up, public investment decisions regarding biojet should account for societal costs and benefits. The playing field is not entirely level if one looks simply at the market price of conventional jet fuel versus biojet in dollars per gallon. The true social costs of fossil fuels include costs to future generations of current greenhouse gas emissions. Yet even with a generous allowance for societal benefits, it is difficult to make a case for biojet in an era of low-priced fossil fuels since massive public subsidies would be required at present. Relative to the aviation sector, it may be easier or more cost-feasible for other energy-intensive sectors of the economy (such as road transportation) to find ways to reduce carbon emissions. If that is the case, aviation’s share of global carbon emissions can be expected to keep rising, especially as demand for air travel continues to be strong.

For More Information

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