Economy-Wide Impacts of Forest Bioenergy in Florida: A Computable General Equilibrium Analysis

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Abstract

Florida has high potential to produce forest biomass as a source of renewable energy because of favorable climate. The Florida government has developed renewable bioenergy programs and policies to reduce the cost of biofuel and to compete with fossil fuel, such as the Florida Renewable Energy Technologies & Energy Efficiency Act. The main purpose of this paper is to investigate the economy-wide and welfare effects of select bioenergy polices in a computable general equilibrium (CGE) modeling framework. This study simulated two scenarios: the implementation of an incentive for the production of second generation bioenergy and a scenario anticipating technological gains in forest bioenergy production. The modeling experiments resulted in increased welfare and gross state product, and land shifting from agriculture to forestry. Results indicate that an incentive for the second generation bioenergy sector and investment in technology would result in overall positive outcomes for Florida’s economy and household welfare.

Keywords: Renewable energy; Computable general equilibrium (CGE) model; Forest bioenergy; biofuels; economy impacts
Introduction

The trend of energy consumption in the United States (US) has been on the rise. Given declining domestic production of crude oil, increased demand for energy is anticipated to be met to a large degree with significant growth in imports. About 58% of the current oil consumption is imported indicating a high level of dependency on foreign oil (EIA, 2008a). National security concerns associated with dependency on foreign oil are prompting policy-makers to look for alternatives. Meanwhile, the US greenhouse gas (GHG) emissions in 2007 were about 7,282 million metric tons of carbon dioxide equivalents\(^1\). Fossil fuel combustion was responsible for 82.3% of these emissions (EIA, 2008b) which is the largest source of anthropogenic GHGs (IPCC, 2001). Unlike fossil fuel, bioenergy is thought to be environmentally benign, socially desirable, and even economically competitive. According to the EIA (2008c), liquid biofuel production is expected to grow by 3.3% per year until 2030 in the US, though fossil fuel will still supply 79% of total energy use in 2030.

Bioenergy produced from grain-based materials, such as corn and wheat is known as first generation bioenergy. Some studies have shown that the energy content of grain-based bioenergy is lower than conventional energy and may compete with food and feed crops for land, water and other inputs (Childs and Bradley, 2007; Kojima et al., 2007; Fargione et al., 2008). These findings have driven research into second generation bioenergy, which is produced from cellulosic materials. Recent research has identified a number of advantages of second generation bioenergy over its predecessor. Second generation bioenergy can reduce competition between crops destined to food and those designated to fuel production; second generation biofuels have a greater net energy balance; second generation bioenergy leads to greater reductions in GHG emissions (Hill et al., 2006; Marshall and Greenhalgh, 2006; Dwivedi and Alavalapati, 2009 ); the use of logging residues to produce electricity can be highly cost-effective when coal-fired electricity plants are assessed emissions taxes (Gan and Smith, 2006); and, the removal of small diameter forest biomass (which may be used to produce fuel), can improve forest health, enhance biodiversity, and reduce wildfire risk (Polagye et al., 2007).

In 2007, the US government established the Energy Independence and Security Act setting a goal to produce 36 billion gallons of biofuels by 2022. Of that, corn ethanol production is capped at 15 billion gallons per year starting in 2015, and the remainder is anticipated to be met by cellulosic-based biofuels. This policy is expected to stimulate new market opportunities for forest biomass. At the same time, the Florida government has also initiated bioenergy programs and policies to promote bioenergy. One such policy is the issuance of tax credits for energy efficient products through the Florida Renewable Energy Technologies & Energy Efficiency Act of 2006. Meanwhile, Florida has more than 16.5 million acres of forestland that have a high potential for producing forest biomass that can be utilized to produce liquid biofuels or to generate electricity through co-firing.

This study applies a computable general equilibrium (CGE) model (Lofgren et al., 2002; Holland et al., 2007) since it is effective in shedding light on important inter-sectoral linkages and in capturing the economy-wide impacts of policy implementation. The CGE model has been

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\(^1\) Carbon dioxide equivalent is a metric measure used to compare the emissions from various GHGs based upon their global warming potential (GWP). Carbon dioxide equivalents can be expressed in "million metric tons of carbon dioxide equivalents (MMTCDE)" (EPA, 2008b).
applied to assess the effects of environmental policies and bioenergy issues. Kretschmer and Peterson (2008) classified three approaches, which are disaggregating bioenergy production sectors directly form a social account matrix (Taheripour et al., 2008), implicit approach, and latent technologies, to introduce bioenergy into the CGE modeling frameworks. The implicit approach complies with a biofuel policy target to avoid breaking up of the original model structure (Banse et al. 2008). The latent technologies refer to existent production technologies, which are not active in the base year, would be active in counterfactual scenarios (Reilly and Paltsev, 2007). Research has shown significant shifts in land use resulting from the implementation of US and EU bioenergy policies (Banse et al., 2008; Taheripour et al., 2008; Kancs and Wohlgemuth, 2008). Abdula (2006) showed that incentives for biofuels production result in afforestation or plantations for bioenergy production, such as switch-grass. Reilly and Paltsev (2007) found that a biofuel industry that supplies a substantial share of liquid fuel demand would have very significant effects on land use and conventional agricultural markets in the US.

Although many studies can be found which explore bioenergy issues, an economy-wide analysis in Florida or in the US Southern region is still rare. Hence, in a general equilibrium framework, this study seeks to understand the socioeconomic impacts of bioenergy policies in Florida with specific attention to the impacts on related markets such as agriculture and forestry and the trade-offs between sectors. The following section provides an overview of bioenergy policies in Florida. Section 3 presents the modeling framework, the data, and the scenarios to be implemented in the analysis. Results and discussion are provided in section 4. The paper concludes with a summary of the key findings, policy implications and future research directions.

Bioenergy policies and programs in Florida

Florida consumes approximately 9 billion gallons of fossil fuels, which makes up about 97% of total energy consumption, and it ranks third in total energy consumption and fifth in energy consumption per capita in the US. Moreover, with a growing population, Florida’s electricity consumption is expected to increase by about 30% by 2016 (FDEP, 2006). Thus, Florida needs clean, affordable, and sustainable energy sources to support the future economy, maintain a high quality of life, and insure energy security. Research has indicated that Florida is the state with the highest potential to produce biomass products. Florida has approximately 16.5 million acres of forestland and its forest sector produced about 2.5 million tons of mill residues in 2007 (USFS, 2008). As such, Florida has the potential to supply over 30% of its transportation fuel demand from forest/cellulosic biomass (UF/IFAS, 2006).

While the federal government signed the Energy Independence and Security Act of 2007, the Florida state government also initiated programs to promote bioenergy. The 2006 Florida Energy Act established the Florida Energy Commission and the Florida Renewable Energy Technologies & Energy Efficiency Act. Some of the programs related to bioenergy include the Renewable Energy Grant program, the Bioenergy Grant Program, and the Renewable Energy Corporate Tax Program. The Renewable Energy Corporate Tax program includes a sales tax exemption on the sale or use of specific “clean fuels”, such as biodiesel and ethanol and an investment tax credit of 75% of all capital costs, operation and maintenance costs, and research and development costs for biofuel production. The legislation also amended the Florida Power Plant Siting Act to streamline permission for new power plants and to promote the development and use of biodiesel, ethanol, hydrogen, and other renewable fuels.
In 2006, the government of Florida established the Florida Farm to Fuel Initiative to enhance the market for and promote the production and distribution of renewable energy from Florida-grown crops, agricultural waste, and wood residues. The initiative includes an education program and a comprehensive statewide information campaign to educate the public about the benefits of renewable energy and the use of alternative fuels, particularly ethanol.

Furthermore, the Florida government passed a comprehensive energy bill in 2008 that created new programs associated with bioenergy (2008 FL H.B.7135). The bill set a renewable fuel standard mandating that all gasoline sold in Florida must contain 10% ethanol by volume by the end of 2010. It established an ethanol production credit as well whereby county governments are eligible to receive waste reduction tax credits for the use of yard clippings, clean wood waste, or paper waste as feedstock for the production of clean-burning fuels. Impacts of these policies are expected to have spill-over effects on all sectors of the state economy and assessing them is critical for further decision-making.

**Modeling framework**

This study applies a CGE model developed by Lofgren et al., (2002) and customized by Holland et al., (2007) for compatibility with the IMPLAN (IMpact analysis for PLANning) data set to assess policy impacts. Some of the adjustments to the model include a more robust representation of transfers between institutions and the inclusion of indirect business taxes. In addition, we model that the government, investment account, and households receive income from the primary factors of production.

In the modeling framework, producers are modeled to maximize profits with a two-level production technology. At the first level, intermediate and primary inputs (labor, capital, and land) are demanded in fixed proportions to produce each unit of output. At the second level, the aggregate intermediate input is specified by a Leontief function of disaggregated intermediate inputs, while value added is captured by a constant elasticity of substitution (CES) function of the primary inputs.

The institutions in the model are: three household income classes, the state and federal government (including investment and expenditure), general investment, and the rest of world. The households receive income from the primary factors of production and transfers from other institutions; they make payments to the direct tax account, save, consume, and make transfers to other institutions. Household consumption is assumed to maximize a Stone-Geary utility function, which leads to linear expenditure system (LES) demand functions. The government collects taxes, which are at fixed ad valorem rates, and receives transfers from other institutions. Government consumption is fixed in quantity and government transfers to households and the investment account are indexed by the consumer price index (CPI). The general investment institution receives payments from the primary factors and transfers from other institutions. Investment demand is fixed and defined as the base-year quantity multiplied by an adjustment factor. Transfer payments from the rest of the world, domestic institutions, and factors are all fixed in foreign currency.

Regarding trade, domestic and imported goods are considered imperfect substitutes by the Armington assumption which applies a CES function to aggregate domestic and imported goods to produce a composite good. The demand of each sector’s output is obtained by minimizing the cost of the composite good subject to the CES function. Composite commodity supply is a function of the price of imports and the price of regionally produced commodities. The export
supply function is derived from a constant elasticity of transformation (CET) function. It specifies the value of exports based on the ratio of domestic and export prices. The CET function assumes imperfect substitutability between products produced for the domestic and export market by a given industry.

Equilibrium prices are endogenously determined (commodity prices, factor prices and the exchange rate) to clear the product, factor, and foreign exchange markets. The parameters of these functional forms are calibrated with the Florida SAM. With regards to factor closures, labor supply is modeled as flexible in supply and mobile across sectors within the state, capital is activity-specific and fixed, and land is fixed in supply and mobile across sectors. The foreign exchange rate is assumed flexible and the import price is a function of the world price, the import tariff and the exchange rate. Total investment is treated as exogenous with outside capital flows adjusting to equate total savings with the investment. The CPI is set to be the numeraire. The GAMS (General Algebraic Modeling System) software is used to solve the model as a mixed complementary problem by using PATH solver.

Data Base

The database is derived from 2006 Florida IMPLAN data and includes 509 sectors\(^1\). To simplify the model, the 509 sectors were aggregated into 11 sectors, namely: agriculture, logging, sawmill products, pulp and paper products, other wood products, conventional energy, manufacturing, transportation, first generation bioenergy, second generation bioenergy sectors, and other sectors. The sector code 151 in the IMPLAN data, *other basic organic chemical manufacturing*, represents the first generation bioenergy sector. IMPLAN does not provide explicit information on second generation bioenergy since the level of second generation bioenergy output was very low in 2006. Thus, the intermediate consumption and primary factor consumption of second generation bioenergy sector data is disaggregated from the logging, sawmill, and pulp-mill sectors by a small ratio based on the literature (Kretschmer and Peterson, 2008; Taheripour, *et al*., 2008). With regards to households, IMPLAN describes nine household-income classes. To simplify analysis, households were aggregated into three income categories, namely: low (income less than $25 thousand dollars), medium ($25–75 thousand dollars), and high (greater than $75 thousand dollars) income categories.

The policy scenarios

This research investigates two specific scenarios based on the policies discussed in section 2 to analyze the economy-wide and welfare impacts of biofuels production in Florida. The following scenarios were considered:

A. Bioenergy incentive

Since rising GHG emissions are leading a shift from fossil fuels to renewable energy sources, a price support for bioenergy or a tax on conventional energy could be used to simulate shifting preferences for clean and efficient energy sources. Currently, most ethanol subsidies are applied to grain-based ethanol, or first generation bioenergy production. To encourage the

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\(^1\) Between 1990 and 2000, IMPLAN data included 528 sectors based on the Standard Industrial Classification (SIC) system. From 2001 onward, datasets were modified to include 509 sectors based on the North American Industry Classification System (NAICS) codes.
development of forest bioenergy, a 10% fuel tax reduction is applied to the second generation bioenergy sector. This tax reduction can be considered a subsidy for cellulosic bioenergy production.

B. Technological progress

Due to the high cost of energy production from woody biomass with current technology, energy companies are still less likely to use biomass in energy production. There are a number of policy alternatives that may be implemented to increase bioenergy production. Policy incentives to reduce the cost of biomass transportation or a production subsidy would stimulate bioenergy production. Cost-sharing capital investments in constructing woody fuel bioenergy plants would lead to the reduction in the unit cost of bioenergy production. Stimulating technological gains in bioenergy production would also reduce production costs. In this scenario, anticipated technological gains are simulated as a 10% reduction in the second generation bioenergy sector’s intermediate consumption of logging, sawmill products, and pulp-mill products.

Simulation results

In this section, simulation results are presented and interpreted. The results report the policy simulation effects on supply price and quantity, government expenditure and investment, factor demand, and welfare.

Supply price and quantity

The price of the second generation bioenergy commodity decreases by -0.10% while there are insignificant changes in the other sectors in the bioenergy incentive scenario (Table 1). Most of the supply prices decline with the exception of the agriculture, conventional energy, and other sectors in the bioenergy incentive scenario. For the technological progress scenario, the supply price of second generation bioenergy drops by -1.75%. The supply price of agriculture, logging, pulp-mill products, conventional energy, and other commodities increase, while sawmill products, other wood products, manufacturing, transportation, and first generation bioenergy decrease. With an increase in the price of logging and pulp-mill products in the technology scenario, we may expect landowners to increase the level and frequency of forest thinning to benefit from the price increase. Furthermore, since second generation bioenergy is a kind of alternative energy, the price of conventional energy increases slightly when the price of second generation bioenergy decline in both scenarios.

Table 1 Percent change in producer commodity prices

<table>
<thead>
<tr>
<th></th>
<th>Bioenergy Incentive</th>
<th>Technological progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0.000003</td>
<td>0.000084</td>
</tr>
<tr>
<td>Forest products and logging</td>
<td>-1.35E-07</td>
<td>0.000194</td>
</tr>
<tr>
<td>Sawmill products</td>
<td>-3E-06</td>
<td>-4E-06</td>
</tr>
<tr>
<td>Pulp and paper products</td>
<td>-2.29E-09</td>
<td>1.87E-08</td>
</tr>
<tr>
<td>Other wood products</td>
<td>-1E-06</td>
<td>-2.3E-05</td>
</tr>
<tr>
<td>Conventional energy</td>
<td>1.46E-07</td>
<td>7.74E-07</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>-1.23E-08</td>
<td>-3.46E-07</td>
</tr>
<tr>
<td>Transportation</td>
<td>-1.25E-07</td>
<td>-3E-06</td>
</tr>
<tr>
<td>Others</td>
<td>1.42E-07</td>
<td>0.000001</td>
</tr>
<tr>
<td>First generation bioenergy</td>
<td>-1.27E-07</td>
<td>-3E-06</td>
</tr>
<tr>
<td>Second generation bioenergy</td>
<td>-0.09592</td>
<td>-1.74794</td>
</tr>
</tbody>
</table>
Since the share of the second generation bioenergy production in total economic output is very small, it is not expected that the supply of this commodity would change much in the scenarios. What is interesting, however, is the direction of effect the policy simulations have on commodity supply. The supplies of all commodities rise in both scenarios with the exception of the agriculture sector (Table 2). The quantity of second generation bioenergy supply increases by 0.18% in the incentive scenario and by 3.49% in the technology scenario.

Table 2 Percent change in quantity of commodity supply

<table>
<thead>
<tr>
<th></th>
<th>Bioenergy Incentive</th>
<th>Technological progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-2E-06</td>
<td>-0.00011</td>
</tr>
<tr>
<td>Forest products and logging</td>
<td>0.000094</td>
<td>0.003545</td>
</tr>
<tr>
<td>Sawmill products</td>
<td>0.000011</td>
<td>0.000194</td>
</tr>
<tr>
<td>Pulp and paper products</td>
<td>0.000011</td>
<td>0.00015</td>
</tr>
<tr>
<td>Other wood products</td>
<td>0.000003</td>
<td>0.00004</td>
</tr>
<tr>
<td>Conventional energy</td>
<td>4.17E-07</td>
<td>0.000006</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>5.57E-07</td>
<td>0.000007</td>
</tr>
<tr>
<td>Transportation</td>
<td>0.000001</td>
<td>0.000018</td>
</tr>
<tr>
<td>Others</td>
<td>2.90E-07</td>
<td>0.000002</td>
</tr>
<tr>
<td>First generation bioenergy</td>
<td>0.000002</td>
<td>0.000037</td>
</tr>
<tr>
<td>Second generation bioenergy</td>
<td>0.18476</td>
<td>3.490816</td>
</tr>
</tbody>
</table>

**Primary factor demand and the government**

With a flexible labor supply, all sectors demand more labor with the exception of second generation bioenergy. This may be explained by the fact that intermediate inputs and primary factor inputs are aggregated in fixed shares. The results show that the intermediate inputs increase by 0.19% and 14.05% for second generation bioenergy in the bioenergy incentive and technological progress scenarios, respectively. Hence, with a fixed labor wage and flexible labor supply, the second generation bioenergy sector demands less labor in both scenarios. The price of capital also increases marginally for all sectors and decreases for the second generation bioenergy sector in order to clear the capital market. Both scenarios result in reduced unemployment. With fixed land supply, there is a contraction in agricultural demand for land and an increase in the logging sector’s demand for land in both scenarios (Table 3).

Table 3 Percent change in demand for land

<table>
<thead>
<tr>
<th></th>
<th>Bioenergy Incentive</th>
<th>Technological progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>-8E-06</td>
<td>-0.00031</td>
</tr>
<tr>
<td>Forest products and logging</td>
<td>0.000118</td>
<td>0.004452</td>
</tr>
</tbody>
</table>

The impacts of the policy simulations on the government are presented in table 4. The federal government revenue increases as federal expenditure decreases; the state government revenue and expenditure increase slightly in both scenarios. Meanwhile, the federal and state governments collect more indirect business taxes in both scenarios.
Household and welfare impacts

Net household income increases for all household income classes in both scenarios (Table 5). Household utility increases slightly for all household classes in the bioenergy incentive scenario. However, in the technology scenario, household utility declines for low-income households and increases for medium and high-income households. Results show that some commodity supply prices increase, namely agriculture, logging, pulp-mill, conventional energy, and other products. Thus, the negative impact on low-income households may be explained by a negative substitution effect which is greater than the positive income effect.

Table 5 Percent change in household (HH) utility

<table>
<thead>
<tr>
<th>Numbers of HH</th>
<th>Bioenergy Incentive</th>
<th>Technological progress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low HH</td>
<td>838,866(18%)</td>
<td>1.35E-09</td>
</tr>
<tr>
<td>Medium HH</td>
<td>2,264,843(49%)</td>
<td>1.02E-08</td>
</tr>
<tr>
<td>High HH</td>
<td>1,529,265(33%)</td>
<td>1.19E-08</td>
</tr>
</tbody>
</table>

This study also applies the Hicksian equivalent variation (EV) as a measure of both price and income effects rather than simply a measure of change in household income. Equivalent variation is measured at the level of prices and income present prior to the implementation of a policy. It is the minimum payment the consumer would need to forgo the policy change. In other words, it is the amount the consumer would need to receive to be as well-off if the policy had been implemented. For the bioenergy incentive scenario, the EV increases for low, medium and high income classes by $15, $327, and $269, respectively. For the technological progress scenario, the EV decreases for low income households by $340 and increases in the case of medium and high income households by $194 and $319, respectively. Finally, Florida’s gross state product (GSP) increases slightly in both bioenergy incentive and technological progress scenarios by $4086 and $1227, respectively.

Conclusions

Private forests in Florida have high potential to produce forest biomass that can be utilized to produce cellulosic ethanol or to generate electricity through co-firing. It is believed that promoting the second generation bioenergy sector can create job opportunities and stimulate economic growth. This research assessed the socioeconomic impacts of two potential cellulosic bioenergy scenarios on the Florida economy. The scenarios evaluated included a subsidy for the second generation bioenergy sector and a technological improvement in second generation bioenergy production technology. Overall, results indicate that subsidizing the second generation bioenergy sector and technological progress in second generation bioenergy production would lead to increased welfare and GSP, and land shifting from agricultural production to forest-based
activities. The price of first and second generation bioenergy dropped in both scenarios. Both federal and state government revenue increased. Moreover, the technological progress scenario showed that the price of logging and pulp-mill products increased. One implication for landowners is that increasing the level and frequency of forest thinning could result in increased income. In addition, thinning can improve forest health, reduce wildfire risk and enhance biodiversity.

The implementation of incentives for the production of second generation bioenergy may generate new market opportunities for forest biomass and increase the demand for forest bioenergy resulting in overall positive outcomes for the economy. Investment in technology may reduce the cost of bioenergy production and further stimulate the production of forest bioenergy. To maximize positive policy outcomes, complimentary policies may be required to offset the small reduction in the income of low-income households.

Future research directions include the development of a dynamic CGE model to more realistically model policy scenarios and trace socioeconomic impacts through time. A regional dataset is also being constructed for the Southern US region. It would enable a regional approach to the development and implementation of bioenergy and bioenergy feedstock policies.

References

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