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Effect of soil heterogeneity on the welfare economics of biofuel policies

Vincent Martinet*

INRA, UMR210 Economie Publique, F-78850 Thiverval-Grignon, France

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ABSTRACT

Biofuel policies (blend mandate or tax credit) have impacts on food and energy prices, and on land-use. The magnitude of these effects depends on the market response to price, and thus on the agricultural supply curve, which, in turn, depends on the land availability (quantity and agronomic quality) and relative prices. To understand these relationships, we develop a theoretical framework with an explicit representation of land heterogeneity. The elasticity of the supply curve is shown to be non-constant, depending on land heterogeneity and the availability of land for agricultural expansion. This influences the welfare economics of biofuels policies, and the possible carbon leakage in land and fuel markets. We emphasize that the impacts of biofuel policies on welfare and land-use change depend strongly on the potential development of the agricultural sector in terms of expansion and intensification, and not only on its current size.

Introduction

In the last decade, several countries have supported biofuel production and set targets in terms of their use (Sorda et al., 2010). There are a number of political reasons pushing governments to promote biofuels, the main ones being climate change mitigation, employment in the agricultural sector, and energy security (Charles et al., 2007). As biofuel production at a large scale is not profitable in a context of relatively low gasoline prices (apart from the Brazil case), governmental targets would not be achieved without external incentives, and the recent increment in production has been driven by public policies and economic incentives (Kretschmer et al., 2009; Sorda et al., 2010). For example, in the United States, ethanol production is supported by strong tax credits (VEETC: Volumetric Ethanol Excise Tax Credit) as well as by production mandates (RFS: Renewable Fuel Standards). In the European Union, biofuel consumption is also mostly driven by blending mandates and tax exemption. Biofuel policies are strongly distortionary, and generate welfare effects (De Gorter and Just, 2009a,b; Böhringer et al., 2009). In particular, the increasing production of first generation biofuels from grain and oilseeds participates in the increment in food price, jeopardizing food security. Biofuel production also generates environmental externalities, such as green house gases emissions or biodiveristy losses (Fargione et al., 2008; Groom et al., 2008; Petersen, 2008; Tilman et al., 2009). These negative effects are due to land use change on the one hand, and market effects on the other. The magnitude of these effects depends on the elasticities of agricultural supply, and thus on the extensive (land use change) and intensive (intensification of production) margins in the agricultural sector. Biofuel policies may result in carbon leakage in fuel and land markets. In this context, it is important to understand the interactions between market effects and agricultural land-use to assess the holistic effect of biofuel policies.

To assess the environmental effects of biofuel policies, Searchinger et al. (2008) consider response of market, and estimate new crop supply and demand using historical conversion patterns. However, land-use is not modeled directly, and agricultural land expansion is not endogenous. Two main, complementary approaches are used in the literature to investigate the relationship between agricultural markets and land use change: computable general equilibrium (CGE) models and mathematical land-use share models based on partial equilibrium. The main difference between these approaches lies in their degree of complexity, the former approach being based on detailed simulation models, while the latter is based on stylized analytical models.[1] CGE models make it possible to assess the impacts of biofuels policies on land use in a general equilibrium, using land supply curves (Banse et al., 2008; Keeney and Hertel, 2009; Kretschmer and Peterson, 2010). The CGE approach provides powerful tools to simulate policy shocks, and to assess their impact on trade equilibrium. However, these models often assume Constant Elasticities of Substitution and Constant Elasticities of Transformation, and the key drivers of computed phenomena, like land use change, are not always apparent.

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* Tel.: +33 1 30 53 57; fax: +33 1 30 53 68.
E-mail address: vincent.martinet@grignon.inra.fr

[1] Lapand and Moschini (2012) provide an analytical assessment of the welfare effect of biofuel policies in a general equilibrium model without considering land and land-use effects.

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Simpler mathematical analyses, such as land-use share models, make it possible to understand the key elements of the impacts of biofuel policies on land-use change. Evidence from the empirical literature strongly supports the notion that private land-use decisions are determined by the financial returns to different land uses (i.e., the Ricardian rent), and land quality consistently explains the aggregate distribution of land-use (Stavins and Jaffe, 1990; Wu and Segerson, 1995; Hardie and Parks, 1997). For example, high quality land is typically allocated to intensive agricultural uses such as row cropping, while low quality land is often put into forestry. Land-use shares in a given area will depend on the distribution of land quality within this area.[2] Feng and Babcock (2010) use such a land-use share model to assess qualitatively the marginal effects of biofuel policies on land-use change and intensification, around equilibrium. However, biofuels policies are likely to modify agricultural production and consumption more than marginally, and the results of a broader analysis will depend on supply elasticities away from equilibrium (which are likely to be non-constant). This difference matters when one focuses on the welfare effects of biofuel policies. De Gorter and Just (2009b) conclude their article on this point, emphasizing that the shape of the agricultural supply curve is influenced by available land for expansion, which modifies the supply elasticity, and then the deadweight costs of biofuels policies.

The present paper proposes a formal framework to examine how the agricultural soil quality heterogeneity of a country influences the welfare implications of biofuel policies and their effect on land-use change. Our analysis is in line with the welfare analysis of De Gorter and Just (2009a,b), completed by accounting explicitly for soil heterogeneity and its influence on agricultural supply. For this purpose we build on the framework of Feng and Babcock (2010). By specifying the form of the soil quality distribution, we extend their analysis in two directions. Firstly, the proposed extension allows us to determine agricultural supply functions and land supply curves as function of the quality heterogeneity distribution. We build such functions accounting for agricultural land expansion and extensive margins, as well as for intensification and intensive margins (i.e., the increase of input use and yield in response to output price increase). We show that the land quality heterogeneity distribution influences the shape of the agricultural supply function, which is likely to be non-linear.[3] Application of our approach to US and France data illustrates our analytical results and emphasizes the flexibility of the proposed approach. Secondly, the proposed extension allows us to examine the effect of biofuel policies when equilibrium is modified more than marginally. We discuss how the heterogeneity of land quality influences the analysis of welfare implications of tax credit (De Gorter and Just, 2009a; Feng and Babcock, 2010) and blend mandate (De Gorter and Just, 2009b; Feng and Babcock, 2010). As the elasticity of supply curve is not constant, deadweight costs of biofuel policies vary with the availability of additional land in quantity and quality. In particular, the effect of biofuel policies on both land and energy markets have to be assessed to determine if there are carbon leakages in these markets. Our main message is that the consequences of biofuels policies depend on both the global land endowment of the country under study and the position of the equilibrium on the non linear agricultural supply curve. The possibility to develop further the agricultural sector is thus more important than its current size.

The framework proposed here would be helpful for further research examining analytically the indirect land-use change impact of biofuel policies in a context of trade between countries, or world areas, with different land endowment.

Motivation: the welfare economics of biofuel depends on agricultural supply

To motivate our analysis, we develop further the arguments of the introduction, by refering to the example of biofuel tax credits. The welfare implications of a biofuel tax credit has been studied by De Gorter and Just (2009a).

We consider a biofuel sector which produces biofuels from an agricultural commodity, with a constant return technology. For the sake of simplicity we assume that the quantity of biofuel produced B is a linear function of the quantity of agricultural commodity used Q^B, i.e., $B = bQ^B$, where b is the rate of conversion of agricultural biomass in biofuels. Such a simple technology is used, for example, in De Gorter and Just (2009a,b) and Feng and Babcock (2010). The profit of biofuel producers is given by $\pi^B = p^B B - p^A Q^B$, where p^B is the selling price of biofuel, which is assumed equal to the price of oil-based gasoline p^G when there is no mandatory blend.[4] This equation defines a break-even price for the agricultural commodity at level $p^A = \bar{p} \equiv bp^B$. We consider a partial equilibrium of the energy and food sectors.

Fig. 1 presents the welfare analysis of biofuel tax credit, as presented by De Gorter and Just (2009a). Notations are as follows; D^A and D^F are, respectively, the demand for food and fuel. S^A and S^G are, respectively, the supply for food and fossil fuel (gasoline). S^B is the supply for biofuels, given by the difference between agricultural output and food demand. S^B_σ is that supply when a tax credit σ is applied. S^F is the resulting (blended) fuel supply.

Under the assumption of linear biofuel technology, prices of the agricultural output on the left panel and of the fuels on the right panel are proportional. The introduction of a tax credit for biofuels modifies the fuel consumption: total fuel consumption increases and fuel price decreases from p^F_0 to p^F. The quantity of gasoline consumed decreases (gasoline consumption corresponds to the part from the origin to point G). Biofuel consumption is equal to the difference between total fuel consumption and gasoline consumption, i.e., segment GB. Note that the reduction in gasoline use is lower than the quantity of biofuels used (the market equilibrium moves to the right). There is a carbon leakage due to a market effect in the fuel market.

The price of agricultural output is driven by the break-even price of the biofuel industry, and is proportional to $p^F + \sigma$. Food price increases from p^A_0 to p^A. Following De Gorter and Just (2009a), we interpret these changes in equilibrium in terms of welfare.

The deadweight cost[5] of underconsumption of food is given by area a and the deadweight cost of overproduction in the agricultural sector is given by area b. Such costs are usual when a policy such as a subsidy modifies an optimal equilibrium. De Gorter and Just (2009a) show that biofuel tax credit also generates "rectangular" deadweight costs when the price of biofuel without intervention is higher than the fuel price. The two rectangular areas labeled by c and d correspond to the "water" in the tax credit (i.e., the amount of

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[2] Spatially explicit models without soil heterogeneity *à la von Thunen* can also be used to determine the effect of biofuel production on local land use (Lankoski and Ollikainen, 2008).

[3] Using area based models with heterogeneous land quality to build agricultural supply function is a contribution to the literature as such functions are usually constructed from profit functions, or by aggregating technological functions (Arnade and Kelch, 2007; LaFrance and Pope, 2008).

[4] Other inputs could be considered in the biofuel production without modifying the results of the present analysis. Only the break-even price level would change.

[5] In welfare economics, the deadweight costs of a policy correspond to net losses of welfare with respect to an optimal situation, i.e., losses for some agents (consumers, producers or tax payers) which are not compensated by gains for other agents.