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Irreversible investment, uncertainty, and ambiguity: The case of bioenergy sector

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ABSTRACT

We analyze production and investment decisions of an agent in industrial activities that are characterized by two forms of uncertainty: demand uncertainty (in terms of number of buyers) and competitive effect uncertainty (in terms of other energy resource). We apply our model on the bioenergy industries. We compare the case of an ambiguity neutral agent with that of an ambiguity averse agent. We show that the investment decision of an agent depends on the effects of both the capital investment and the level of production on the cost and the uncertainty the agent is confronted with. Moreover, we find that ambiguity aversion tends to decrease the agent's optimal levels of production and investment. Our numerical analysis of the French case illustrates the different effects associated with demand uncertainty and competitive effect uncertainty.

1. Introduction

Investments into renewable technologies will have to develop in order to reach the renewable energy target of 20% fixed by the European Union (EU) for 2020.[2] To reach the future targets set out by the EU, significant amounts of biomass and investments into biomass based technologies will be necessary.[3] Biomass is key to the development of renewable energies, but it must undergo a pretreatment and densification process before it can be transported and stored. Indeed, biomass is a resource that is heterogeneous in quality and is not homogeneously distributed across space. Therefore, the large range of biomass types is not directly usable in some feeding systems and conversion processes. Investment in new pre-treatment facilities is a necessary step in the total biomass supply chain in order to save transport, material, handling costs for users and to reduce investments in transformation facilities.

These pre-treatment processes are still in progress and the biomass market is emerging. Although a potential investor has information about the demand and the competitive effect on the supply market, this information still remains imperfect.

Indeed, due to the novelty of this market, the agent cannot get a perfect knowledge on the number of buyers before starting the production. He will either have to supply a few potential buyers such as heat and electricity producers, needing to replace coal, or a larger number of potential buyers including producers of second generation biofuel and heat and electricity producers. This uncertainty then affects the agent's perception of the average price. Here and hereafter, we define this uncertainty as the demand uncertainty.

Moreover, the competition effect from other energy resource on the price of pretreated biomass is also not well-known by the agent. In fact, the biomass may be sold either to heating or power units as a substitute for coal (the selling price could then be indexed with coal prices) or to Biomass to Liquid (BtL) units as a substitute for fossil fuel and prices could then be indexed with oil prices, which fluctuate even more sharply than coal prices. So, uncertainty about competition affects the agent's perception of the average price and mostly the variance price. We define this uncertainty as the competitive effect uncertainty.

Considering these two kinds of uncertainty and their impact on the selling price, a biomass agent has to decide how much capital investment and produced units he will make in biomass activities. Capital investment, also called in the literature the cost of entry, in

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[1] Climate Economics Chair.
[2] In 2007, the European Commission has fixed the renewable energy target in the EU's overall mix to 20% in the final energy consumption by 2020 regarding 1990. To reach this goal, the member states have adopted the pack energy-climate and renewable energy (European Commission, 2009) in particular which defines the operational measures to develop 20% of renewable energies by 2020.
[3] Currently biomass delivers around 4% of the EU's primary energy (EEA, 2008).

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bioenergy production represents a quasi-sunk cost due to the fact that biomass torrefaction is a specific, and relatively expensive, process. This naturally raises the issue of the effect of both types of uncertainty and of the irreversibility on the investment level and production.

Furthermore, in the energy market, the instability of the economy may lead the agent to have uncertainties about his evaluation of the variance of the output price. We use the term 'ambiguity' to indicate situations in which the odds of an uncertain event are not precisely known. In other words, a situation in which there is an 'uncertainty about uncertainty'.[4] An agent who has doubts about the odds is considered as an ambiguity-averse agent. So a question arises: how an ambiguity-averse agent behaves when he makes his decisions concerning investment and production?

To understand the impact of uncertainty on investment and production in biomass activities, we propose a two-period model in which there is incomplete information about the number of buyers and the competitive effect. Under these uncertainties, an agent has to choose his capital investment for the production of pre-treated biomass units at the following period. We study the cases of an ambiguity-neutral agent and of an ambiguity-averse agent. Following Klibanoff et al. (2005), we extend our work by presenting ambiguity as a second order prior probability distribution over the set of plausible distributions of the competitive effect. This approach allows us to analyze the impact of ambiguity on the investment and production choices.

The standard theory of irreversible investments or quasi sunk cost (Henry, 1974; Sutton, 1991) and options values suggests a negative relation between investment and uncertainty (Dixit and Pindyck, 1994). Empirical studies also confirm this negative relation (Bond et al., 2005; Carruth et al., 2000; Fan and Zhu, 2010). However, (Kulatilaka and Perotti, 1998; Sarkar, 2000) point out that an increase in uncertainty could increase the probability of investing, and thereby has a positive impact on investment. Moreover, Mohn and Misund (2009) argue that any positive impact on investment arising from the fact that greater uncertainty, under certain circumstances, increases the marginal profitability of capital. In all these papers the effect of price uncertainty has been analyzed as the effect of demand uncertainty on capacity choice (Dangl, 1999; Elder and Serletis, 2009, 2010; Isik et al., 2003; Trigeorgis, 1996). Considering real options approach, Murto et al. (2004) are interested with in the timing of investment projects under demand uncertainty and oligopolistic competition. The important characteristic is that the output price is influenced by both exogenous uncertainty and new capacity investments. This paper is closed to our approach with demand uncertainty and competitive effect even if there is no real uncertainty on the competition. Murto (2006) introduces two types of uncertainty by combining effect of technological uncertainty and uncertainty in output price with real options approach. However, no work has been done on the two types of uncertainty (demand uncertainty and competitive effect uncertainty) that affect prices in different ways: the perception of the average and the variance of the price. Concerning ambiguity, we refer to the basic literature on ambiguity with (Ellsberg, 1961) and Fellner (1961, 1965), the empirical investigations by (Slovic and Tversky, 1974) and the recent literature with (Klibanoff et al., 2005) and Gollier (2006) to indicate situations for which the odds of an uncertain event are not precisely known. Determining how an ambiguity-averse agent decides to invest and produce in emerging technologies is an important line of research in entrepreneurial decision-making in BtL.

Using an analytical approach and numerical analysis, we first note that whatever the certainty or uncertainty context, the agent never invests or produces when he thinks that an increase in capital increases the cost of one more unit. Moreover, we show that the agent's capital investment decision depends on the effects of the amount of capital invested, of the level of production on the cost and on the uncertainty to which the agent is confronted. Then, we observe asymmetric effects of demand uncertainty and competitive effect uncertainty on the optimal amount of investment and optimal production. Finally, we find that ambiguity aversion tends to decrease the agent's level of capital investment and production.

The French biomass pre-treatment industry (torrefaction) is taken as an example, and the empirical results show that the model developed here can provide useful advice for pre-treatment biomass investment programs.

The remainder of the paper is organized as follows. Section 2 consists of a description of the model. Section 3 analyzes and compares the optimal investment and production decisions of both an ambiguity neutral agent and an ambiguity averse agent. Section 4 presents a numerical analysis. Finally, Section 5 concludes.

2. Model description

We consider a two period model with a risk-neutral agent. The agent faces two types of uncertainty: demand uncertainty, in terms of number of buyers, and a competitive effect uncertainty. Indeed, whereas the agent knows that he is competing on the market of fuel providers,[5] *i.e.* he is a price taker,[6] he only has a subjective perception of his potential customers and of the severity of the market competition. Both types of uncertainty affect prices in different ways: the demand uncertainty pertains to the perception of the price average while the competition effect uncertainty pertains to the average and mostly the price variance.

We define four possible states of the world: a Low number of buyers and a Weak competition effect (*LW*), a High number of buyers and a Weak competition effect (*HW*), a Low number of buyers and a Strong competition effect (*LS*) and High number of buyer and a Strong competition effect (*HS*). We propose to divide the agent's subjective probabilities on these states in two kinds of beliefs: first, the agent's subjective probabilities are ψ on the low number of buyers, and $(1-\psi)$ on the high number of buyers; second, the agent's subjective probabilities are θ on the strong competition, and $(1-\theta)$ on the weak competition. In addition, we consider that the 'right' value of the probability associated with the competitive effect uncertainty θ may be unknown. In this case, θ is a random variable, and it is called $\tilde{\theta}$. The agent associates a probability distribution $F(\theta)$ on $[\underline{\theta}, \overline{\theta}]$ which measures the subjective relevance of a particular θ probability. The competitive effect is then ambiguous in the sense that his beliefs depend on a probability distribution. Instability in the energy market can cause the agent to become uncertain about the true value of probability θ, which pertains to the variance of the output price. So there may be a great deal of ambiguity associated with the competition based on the output selling price.[7] Following Klibanoff et al. (2005), we describe the agent's behaviour towards ambiguity by a function ϕ. An increasing and concave ϕ means that the agent is ambiguity averse. Similarly, ambiguity neutrality is characterized by the linear function ϕ.

We associate a selling price P_i with each state $i \in \{LW, HW, LS, HS\}$. A larger number of buyers is likely to be able to support a higher

[4] For more details on ambiguity approach, see Camerer (1999); Etner et al. (forthcoming).

[5] Indeed, the agent knows that there already exists substitute of pre-treatment process which could provide the biomass consumers.

[6] The energy price is determined by the total supply of energy and each unit considers the price as given. Then we do not consider the impact of additional capacity on price.

[7] In a context in which there are two uncertainties affecting simultaneously the level and the variability of the price, an agent is more sensitive to the price variability than to the price average. The demand uncertainty affects the perception of the average price while the competitive effect uncertainty affects the perception of the average price and mostly the variance price. Therefore, we assume an ambiguity associated with the competition effect uncertainty.