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Forest carbon sequestration supply function for African countries: An econometric modelling approach

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ABSTRACT

Carbon sequestration cost function for developing nations particularly Africa plays a vital role in global climate change policy. Based on this, the study estimates carbon sequestration supply function for African countries. The study shows that majority of the selected countries have their cost of carbon sequestration estimated at $14 per ton per ha. Botswana and Congo DRC represent African countries with high cost of carbon sequestration with $16.75 and $16.77 respectively. Nigeria however, has her average cost of carbon sequestration as low as $6.82. The regression result shows that carbon sequestration supply ($p < 0.01$), deforestation ($p < 0.01$) and forest area ($p < 0.01$) are the factors influencing cost of carbon sequestration among the sub-Saharan African countries. The overall marginal cost which is the cost per unit land area required to drive land use change towards carbon sequestration was estimated at $13.30 per ton/ha in Africa. Nigeria, Mali and Chad however, show a relatively low marginal cost of $7.0, $8.0 and $9.0 respectively. The study however suggests that positive land use characteristics should be encourage among countries in Africa, particularly in Nigeria with the least marginal cost of carbon sequestration. This will help in reducing cost of carbon sequestration and thereby lowering the global effect of climate change.

1. Introduction

Greenhouse gases (especially carbon) have been found to be the major cause of global warming and developed nations of the world have been found to be the major emitters of carbon (Bala, 2014). Natural forests store a large quantity of carbon, thereby acting as "sinks" to heat trapping "greenhouse gas" providing means of addressing global warming (Condit, 2008). Increasing concerns about the threat of global climate change has brought with it greater attention to the possibility of encouraging the growth of forests as a means of removing carbon dioxide (CO_2) from the atmosphere (Lubowski et al., 2006). Studies have suggested that forestry-based carbon sequestration is a relatively inexpensive means of regulating carbon emission among developed nations against other means of carbon abatement (Dudek and LeBlanc, 1990; Sedjo and Solomon, 1989).

The need to reduce carbon emission has enhanced investment in forest based carbon sequestration particularly in developing countries by the major carbon emitting countries like USA, China, Japan etc. following different carbon trade mechanism established by the Kyotol protocol (IPCC, 2007; Nobi, 2013).

Globally, Africa particularly the sub Saharan African (SSA) are naturally endowed with forest area with which a large number of global carbon could be stored (Dieng et al., 2009). Unfortunately, the rate of deforestation and other unhealthy land use practices in this region of the world has contributed to global carbon emission rather helping the situation (FAO, 1999). It should be noted however, that most SSA countries are agrarian in nature with increasing population. This peculiarity contributes to increasing land use conversion (i.e. more deforestation) with less concern for the environment.

Substantial effort has been contributed towards ensuring carbon sequestration potential of SSA countries (Rohit et al., 2006). These include project implementations that will ensure reducing deforestation, afforestation, reforestation etc. with the aim to reduce cost of carbon sequestration globally particularly for high carbon emitting countries – as part of the flexibility of kyotol protocol.

Achieving land use change in SSA may results in conversion of land from the existing use (agriculture) to forest through afforestation and or reforestation. The cost of achieving these land use change among SSA countries plays an important role in determining whether developed nations would meet their emission target through flexible mechanism.

Hence, if the developed nations are to receive carbon sequestration services from African countries, the cost of carbon sequestration would be the major determinant. This however, is influenced by land use characteristic like deforestation halt, afforestation, reforestation among

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others (Nobi, 2013).

Therefore, the study seeks to estimate carbon sequestration supply function in SSA by estimating the marginal cost required per unit land area in driving land use towards carbon sequestration among the selected SSA countries, and discuss the implications of the estimated cost in relative to carbon market participation and climate change policy.

2. Literature review

2.1. Methodological review

There have been three main approaches used in estimating cost of carbon sequestration: "bottom-up" engineering models, sectoral optimization studies, and econometric models. According to Dempsey et al. (2009) these different cost estimation methods do not provide consistent cost estimates of forest-based carbon sequestration. It is important to understand the effects of the calculation method on the final results before accepting the cost estimates provided by any study.

Although, each of the three cost estimation approaches are concerned with measuring opportunity costs – what the landowner gives up when he or she converts land from a non-forest use such as agriculture to forest. Bottom-up and sectoral optimization methods measure these costs as the lost profits from the original use (e.g., agriculture) plus costs of establishing trees. Econometric approach, on the other hand, are based on how landowners actually respond to incentives they face in the market place.

As examined by Richards (2004), bottom-up engineering models generally use regional average land prices or land rents to estimate the opportunity cost of converting land from the existing use to another (Dudek and LeBlanc (1990); Moulton and Richards (1990); New York State (1991); Richards et al. (1993); Richards, 1997; Sedjo and Solomon (1989); Van Kooten et al., 1992). These values measure the foregone profits from agricultural production. Usually, the calculated opportunity cost is combined with the conversion costs for moving land from agricultural to forest use, and this becomes the total opportunity cost of the land. Total costs are expressed on an annual basis and divided by an annualized measure of carbon sequestration to obtain the cost per unit of carbon sequestered (or the average cost of carbon sequestration) based on this, the engineering method has advantages of using observable information and transparency of the calculations. However, a downside of the engineering method, and a likely source of the differences in cost estimates provided by the engineering method compared to the econometric approach, is the inability to account for unobservable factors affecting landowner decisions.

The sectoral optimization models typically combine market models of agriculture and forestry and account for the interaction between the two sectors (Adams et al., 1993; Alig et al., 1997; Sohngen and Mendelsohn, 2003). Like engineering models, optimization models are not able to account for unobservable cost and benefits to landowners, however, they do account for the increase in scarcity and, therefore, returns to agricultural land as more land is converted to forestry.

However, the econometric carbon sequestration cost studies analyse data from actual land-use changes with the goal of identifying the relationship between land-use choices and relative returns in the forestry, agricultural, and other land sectors (Stavins and Richards, 2005). Based on this, the econometric calculation method removes a level of uncertainty that is found in many engineering models, leading in principle to more realistic predictions of how landowners will behave. Because they are based on actual historical data, these models can implicitly capture such factors as landowner uncertainty in the face of irreversible investments, non-monetary returns to landowners from forest and agricultural uses of land, liquidity constraints, and other private or market costs or benefits (Lubowski et al., 2006). In addition, the survey based study by Van Kooten et al. (2002) demonstrates why the unobservable incentives that are captured in the econometric method are so important.

Hence, the econometric approach produces higher cost estimates than both the engineering and optimization methods. The most likely reason is that the econometric approach can account for a number of factors that affect land-use decisions in practice, but which are difficult to measure explicitly and include in engineering and optimization models. Several studies have considered the use of econometric approach as a suitable approach to estimating cost of carbon sequestration (Kerr et al., 2001; Newell and Stavins, 2000; Plantinga et al., 1999, and Stavins, 1999).

2.2. Theoretical framework

Producers who desire to earn profits must be concerned about both the revenue (the demand side of the economic problem) and the costs of production. The relevant concept of cost in this aspect is "opportunity cost." This is the value of the next best alternative use of a resource (i.e. land). It is the value sacrificed when a choice is made. The motive for land use diversification among land owners is that of profit maximization utility. The theoretical tools that explains this are utility functions and budget constraints i.e. every producer will wish to maximize profit subject to resource constraint i.e. available land area. For a landowner to shift from one form of land use to another, his aim will be to get higher profit subject to his limited resource.

According to Nobi (2013), let A_0 be the total land supply which the landowner can use in conventional agriculture or in carbon sequestration. It is assumed that every landowner is profit motivated. So, given the available land, they will decide how much land to use in conventional agriculture and for carbon sequestration while the total supply of land is fixed. Then, the objective function of a firm or land owner is to maximize the following profit function (Π) subject to total supply of available land (A_0) (Appendix A).

For a landowner to achieve profit maximization, the marginal net returns of land use in both sectors (agriculture and carbon sequestration) needs to be equal, this is achieved by taking the first derivative which is the necessary condition i.e. First Order Condition (FOC) derived from the Lagrangian which is the marginal return of land use (Appendix A).

That is any firm or landowner will allocate his/her land use in agriculture and in carbon sequestration project in such a way that the marginal net return/profit is equal to ?? in both sectors (Appendix A).

3. Methodology

3.1. Modelling carbon sequestration supply function

The cost of carbon sequestration in carbon reduction project mainly depends on the opportunity cost of land, costs of maintenance, transaction and plantation. Deveny et al. (2009) has made it known that except for the opportunity cost of land, the other costs involved in land use change conversion towards carbon sequestration are negligible, and it considered all other costs as transaction cost (like growing and protecting a forest, human labour cost and machinery) which is estimated only 13% of the project cost.

In addition, the cost function has some exogenous determinants like Clean Development Mechanism (CDM) projects and Per-Capita Gross Domestic Product [GDP]. The GDP was converted to international dollars using Purchasing Power Parity (PPP). Carbon sequestration potential could, in theory, be very significant in terms of the CDM. If there is a CDM project in a country it will affect the rate of carbon sequestration and thereby influencing the cost of carbon sequestration (Cédric et al., 2007). This is because the presence of a CDM projects in a developing country implies that more lands are used in favour of CDM project which will increase the cost of carbon sequestration. Per Capita GDP (in PPP) is the indicator of economic growth and development and hence an indicator of carbon dioxide emission (Kaya, 1990). Economic growth and emission are positively related. Higher economic growth